

## **Scope of Work**

### **Qualitative Survey of of Freshwater Mussels (LBITP)**

**Background:** Unionid mussels are an integral part of freshwater ecosystems and have been recognized as reliable indicators of environmental quality due to their sensitivity to natural occurring and anthropogenic habitat and water quality impacts. Species specific mussel abundance and distribution are primarily influenced by hydrology and benthic habitat and usually prefer moderate to swiftly flowing waters. As a result, mussel populations are highly sensitive to instream flow modification and subsequent scour and deposition. Because of their relative sensitivity and inability to rapidly respond and avoid adverse conditions, over one-half of the approximately 300 species in North America are currently extinct, endangered, or threatened. Although the Texas Parks and Wildlife Department (TPWD) initiated statewide abundance and distribution surveys in January 1992, the existing data for freshwater mussels in Texas is limited. As mentioned, the status of individual mussel populations is sensitive and can fluctuate over small temporal and spatial scales; therefore it is critical to periodically reassess areas capable of supporting freshwater mussels to confirm existing population conditions. Discussions with USFWS suggest a species specific qualitative (presence/absence) mussel survey be conducted at the following locations: the proposed intake (Capers Ridge Pump Station) on the Trinity River, just downstream of the pump station, and at the discharge point located on the East Fork of the San Jacinto River which drains into Lake Houston (Exhibit 1). Existing mussel population data on the mainstem of the Trinity River is lacking and has historically been restricted to the backwaters and tributaries. Conversely, data in Lake Houston immediate watershed indicates the presence of diverse mussel communities but is antiquated and not specific to areas encompassed by this project. Given the limited information available on Texas freshwater mussels in the project area, the proposed surveys will generate useful inventory data for both common and any threatened and endangered mussel species which inhabit these two areas for future use by managers, researchers, and decision makers.

#### **Task 1: Collect mussel distribution, habitat utilization, and related data in the Trinity and San Jacinto River Basins**

Through coordination between USFWS and TPWD mussel surveys will be conducted at predetermined locations on the Trinity River downstream of the Capers Ridge Pump Station and at the outfall location on the East Fork San Jacinto River (Lake Houston). The extent of the survey area will also be coordinated with USFWS and TPWD and is anticipated to encompass the entire river width extending 100 meters downstream from the Capers Ridge Pump Station and approximately 5,000 m<sup>2</sup> surrounding the discharge point at the East Fork San Jacinto River. Survey methodology will be consistent with those described in the East Texas Mussel Survey (Karatayev and Burlakova, 2007).

Task 1 includes depth stratified surveys (e.g. riffle, run, pool) at both locations. The level of effort within each depth strata will be proportional to the acreage of the various depth strata available in the agreed upon survey area in each location. Within each area, a combination of transect and quadrat surveys will be conducted to determine the species specific abundance of mussels present. Transect and quadrat locations will be generated prior to field surveys and will be deployed in the field using a handheld GPS. It is anticipated that transects will be spaced 25 feet apart parallel to the flow and a minimum of 30 quadrats will be surveyed along the transects although this spacing may be modified based on water depth and visibility. The methodology for assessing mussel populations within each transect and quadrat will be based on water depth and visibility and is anticipated to include some combination of wading, snorkeling, and scientific diver surveys.

Within each transect, mussels (dead or alive) encountered will be speciated (if feasible) and returned to their original location. Within each transect, a predefined number of 1m<sup>2</sup> quadrat samples will be collected to assess mussel density. Mussels unable to be identified to species level in the field will be retained temporarily for further analysis. In the event that large quantities of common species are found, an adaptive sampling program will be implemented to sub sample these locations and estimate abundance and density. Threatened and endangered species are not assumed to be found in large quantities therefore it is expected that sub sampling will not be undertaken, and rather all listed species will be counted. Additional data collected within transects will include an assessment of vegetation present, dominant substrates, and other general ecological observations. Dominant substrates will be categorized visually using a modified Wentworth scale. At a representative location within each depth strata at both areas, water temperature, pH, dissolved oxygen, and water conductivity/salinity point measurements will be recorded at the water sediment interface using a calibrated YSI handheld device as water visibility permits, representative photographs of habitat present within each depth strata will be taken. Additional photographs will be taken to inventory mussel species collected. Sampling will be conducted in consultation with the, USFWS and TPWD. A representative from each agency will be notified prior to field sampling events to allow their participation, if desired. Field scientists responsible for mussel speciation will be properly trained and equipped with field guides to properly identify the mussel species with the potential to inhabit the Lake Houston and Trinity River. These include but are not limited to the species identified in the Freshwater Mussels of Texas Distribution Chart (Attachment A).

## **Task 2: Identify mussels, prepare species lists, and report data**

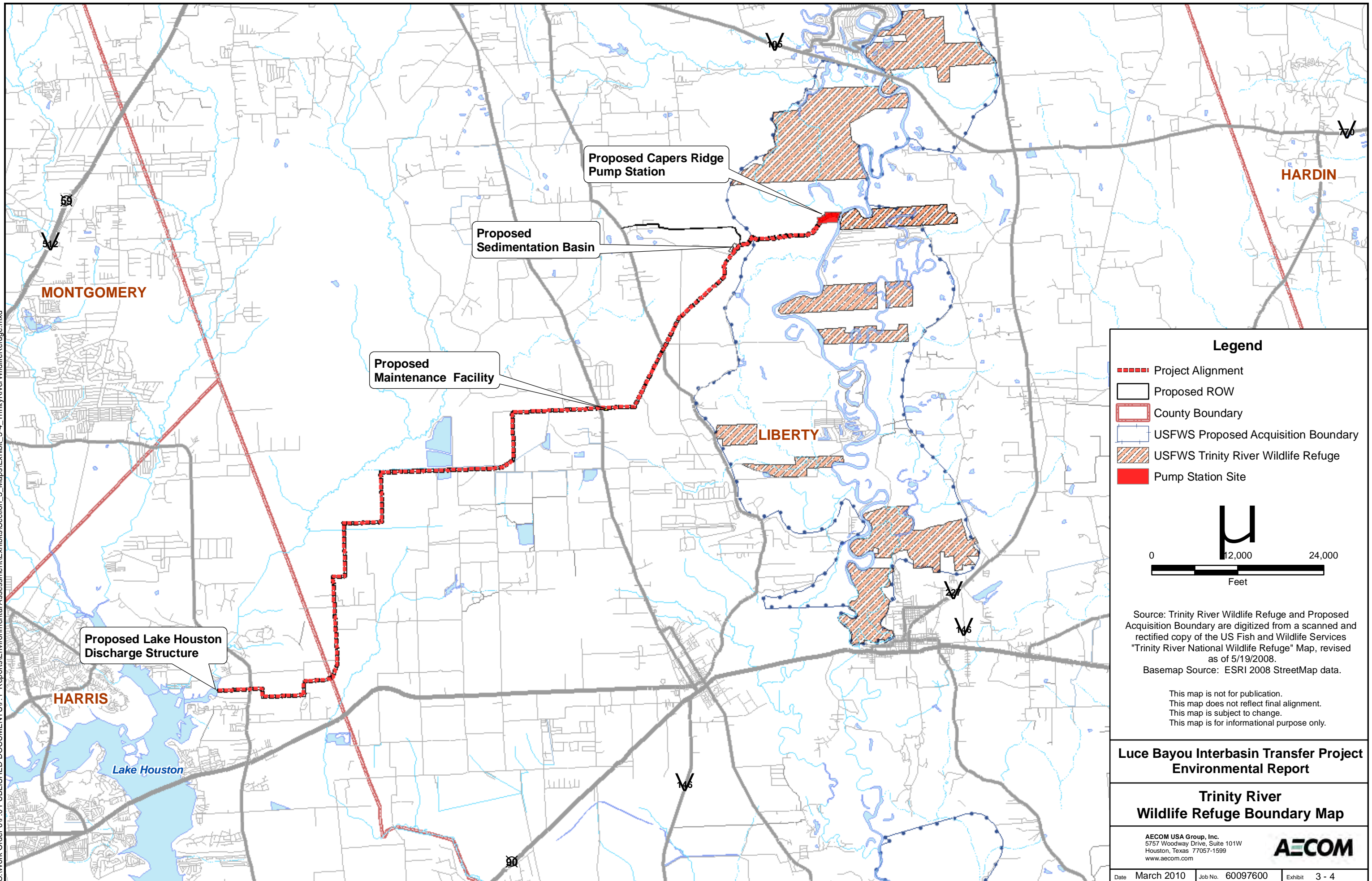
Staff will identify unionids collected in the field when feasible, or preserved and taken back to conduct identifications in the office if they are not listed species. To confirm mussel identification, a small number of representative specimens and/or detailed photographs may be retained and sent to taxonomic experts in mollusks identification at TPWD if desired. At least one individual of each species collected from a sample site will be appropriately vouchered (preserved or adequately photographed). TPWD staff may provide assistance and quality assurance as necessary. A brief report summarizing the results of will be submitted to the appropriate agencies. This report will include a brief narrative explaining the trends in mussel communities observed and also a summary of species specific mussel abundance by habitat in Microsoft Excel format. If warranted, abundance maps will be generated indicating the location (GPS coordinates included) of any threatened and endangered mussel species encountered. Photographs will be submitted in a suitable electronic format, along with metadata providing GPS coordinates, habitat notes, and sampling time/location information.

## **References**

Kuratayev, A. Y. and L. E. Burlakova. 2007. Final Report-State Wildlife Grants Program. East Texas Mussel Survey.

## EXHIBIT 1

O:\Work Order 617.0 PUBLISHED DOCUMENTS\7.1 Reports\Environmental Assessment\Exhibits\Section 3\_Maps\Exhibit 3-4 Trinity River Wildlife Refuge.mxd



## ATTACHMENT A

## Freshwater Mussels of Texas Distribution Chart

This list is intended to serve as a starting point to familiarize yourself with mussel species that may occur in your area. Not all species indicated may still occur within the basin, and some species have very limited distributions within a system. Some species, in addition to those indicated, may occur in your river system. Note species lists for adjacent systems to familiarize yourself with other possible species. Some river systems, such as the Llano, Pedernales, and San Saba, appear to have few or no living mussel populations.

Page	Family: Unionidae	1. Canadian River	2. Wichita River	3. Red River	4. Sulphur River	5. Big Cypress Bayou	6. Sabine River	7. Angelina River	8. Neches River	9. Trinity River	10. San Jacinto River	11. Brazos River	12. Little Brazos River	13. Navasota River	14. Colorado River	15. Concho River	16. San Saba River	17. Llano River	18. Pedernales River	19. San Marcos River	20. Guadalupe River	21. San Antonio River	22. Frio River	23. Nueces River	24. Rio Grande River	25. Devils River	26. Pecos River	27. Lavaca River
1	<i>Amblema plicata</i> (threeridge)			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	X	X	X	O	X			
2	<i>Anodonta suborbiculata</i> (flat floater)			*		*	*	*	*	*	*	*																
3	<i>Arcidens confragosus</i> (rock pocketbook) <sup>6</sup> (TWAP - SC)			X	X	X	X	X	X	X	X	X	X		X					X	X							X
4	<i>Arkansia wheeleri</i> (Ouachita rock-pocketbook) <sup>1</sup> (TWAP - FE)			X																								
5	<i>Cyrtonaias tampicoensis</i> (Tampico pearlymussel)			I						I		X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X
6	<i>Elliptio dilatata</i> (spike)																		O									
7	<i>Fusconaia askewi</i> (Texas pigtoe) <sup>2,3,8</sup> (TWAP - SC)				X	X	X	O	X	X	X																	
8	<i>Fusconaia flava</i> (Wabash pigtoe) <sup>6</sup>			X	X	X	O	X	X	X	X																	
9	<i>Fusconaia lananensis</i> (triangle pigtoe) <sup>2,8</sup> (TWAP - SC) *								X	X																		
10	<i>Glebulia rotundata</i> (round pearlshell)					X		X	X	X	X									O	X						X	
11	<i>Lampsilis bracteata</i> (Texas fatmucket) <sup>6,8</sup> (TWAP - SC)										O			X	X	X	O	O	X	X	X							
12	<i>Lampsilis cardium</i> (plain pocketbook) <sup>9</sup>			X		X																						
13	<i>Lampsilis hydiana</i> (Louisiana fatmucket)			O	X	X	X	X	X	X	X	X								X	X		X					
14	<i>Lampsilis satura</i> (sandbank pocketbook) <sup>2,8</sup> (TWAP - SC)					X	X	X	X	X	X																	
15	<i>Lampsilis teres</i> (yellow sandshell)	?	X	X	X	X	X	O	X	X	X	X	X	X	X	O	X	O		X	X	X	X	X	X	X	X	
16	<i>Lasmigona complanata</i> (white heelsplitter) <sup>2</sup> (TWAP - SC)			X	X				X										O									
17	<i>Leptodea fragilis</i> (fragile papershell)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O										
18	<i>Ligumia subrostrata</i> (pond mussel)				X	X	X	X	X	X	X	X	X	X	X					X	X		X					
19	<i>Megaloniais nervosa</i> (washboard)				X	X	X	X	X	X	X	X	X	X	X	I			O	X	X	X	O	X				
20	<i>Obliquaria reflexa</i> (threehorn wartyback)			X	X	X	X	X	X	X	X																	
21	<i>Obovaria jacksoniana</i> (southern hickorynut) <sup>6,8</sup> (TWAP - SC)			X	X	X	X	X	X	X	X																	
22	<i>Plectomerus dombevanus</i> (bankclimber)				X	X	X	X	X	X	X																	
23	<i>Pleurobema riddellii</i> (Louisiana pigtoe) <sup>2,8</sup> (TWAP - SC)				X	X	X	X	X	X	X																	
24	<i>Popenaias popeii</i> (Texas hornshell) <sup>3,7,8</sup> (TWAP - FC)																							X	X	X		
25	<i>Potamilus amphichaenus</i> (Texas heelsplitter) <sup>2,8</sup> (TWAP - SC)						X		X	X																		
26	<i>Potamilus metnecktaii</i> (Salina mucket) <sup>2,8</sup> (TWAP - SC)																							X				
27	<i>Potamilus ohioensis</i> (pink papershell)		X	X	O	X				X	X	X		X														
28	<i>Potamilus purpuratus</i> (bleufer)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	?	X			I	I	I	?	
29	<i>Pyganodon grandis</i> (giant floater)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	?	X	X	X		X	O		I	
30	<i>Quadrula apiculata</i> (southern mapleleaf)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	X	X	X	X	I		X	
31	<i>Quadrula aurea</i> (golden orb) <sup>6,8</sup> (TWAP - SC)										O			X					X	X	X	X	X					
32	<i>Quadrula couchiana</i> (Rio Grande monkeyface) <sup>5</sup> (TWAP - SC)																							O				
33	<i>Quadrula houstonensis</i> (smooth pimpleback) <sup>6,8</sup> (TWAP - SC)											X	X	X	X													
34	<i>Quadrula mortoni</i> (western pimpleback)				X	X	X	X	X	X	X																	
35	<i>Quadrula nobilis</i> (gulf mapleleaf)			X		X	X		X	X	O																	
36	<i>Quadrula nodulata</i> (wartyback) <sup>3,4</sup> (TWAP - SC)			X		X	O		X																			
37	<i>Quadrula petrina</i> (Texas pimpleback) <sup>6,8</sup> (TWAP - SC)													X	X	X	X	O	X	O	X							
38	<i>Quadrula pustulosa</i> (pimpleback) <sup>6</sup>			X		X				X																		
39	<i>Quadrula quadrula</i> (mapleleaf)		X	X	X	X																						

X = Recent Occurrences (within last 30 years)  
O = Historical Occurrences (>30 years old)

\* = May be introduced  
I = Recently introduced

? = Unknown if population still exists  
September 2009

# Freshwater Mussels of Texas Distribution Chart

Page	Family: Unionidae	1. Canadian River	2. Wichita River	3. Red River	4. Sulphur River	5. Big Cypress Bayou	6. Sabine River	7. Angelina River	8. Neches River	9. Trinity River	10. San Jacinto River	11. Brazos River	12. Little Brazos River	13. Navasota River	14. Colorado River	15. Concho River	16. San Saba River	17. Llano River	18. Pedernales River	19. San Marcos River	20. Guadalupe River	21. San Antonio River	22. Frio River	23. Nueces River	24. Rio Grande River	25. Devils River	26. Pecos River	27. Lavaca River
40	<i>Quincuncina (Quadrula) mitchelli</i> (false spike) <sup>5,8</sup> (TWAP - SC)											O		X		O	O	O	X	X				X		O		
41	<i>Strophitus undulatus</i> (creeper) <sup>2</sup> (TWAP - SC)				X	X	X	O	X	O	O	X		X	O	?	?		O	X	X							
42	<i>Toxolasma parvus</i> (lilliput)			X	X	X	X	X	X	X	X	X	X	X	X		?				X		X	X	X			
43	<i>Toxolasma texasiensis</i> (Texas lilliput)			O	O	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	
44	<i>Tritogonia (Quadrula) verrucosa</i> (pistolgrip) <sup>3</sup>			X	X	X	X	X	X	X	X	X	X	X	X	O	X	O	O	O	X	X						
45	<i>Truncilla cognata</i> (Mexican fawnsfoot) <sup>2,8</sup> (TWAP - SC)																							X				
46	<i>Truncilla donaciformis</i> (fawnsfoot) <sup>2</sup> (TWAP - SC)			X	X	O	O	X	X	X	X																	
47	<i>Truncilla macrodon</i> (Texas fawnsfoot) <sup>6,8</sup> (TWAP - SC)									?	X		X	X	X													
48	<i>Truncilla truncata</i> (deertoe)			X	O	X	X	X	X	X	X																	
49	<i>Uniomereus declivis</i> (tapered pondhorn)				X	X	O		X	X	X	X		X	X							X					O	
50	<i>Uniomereus tetralasmus</i> (pondhorn)		X	X	O	X	X		X	X	X	X	X	X	X				X	X		X						
51	<i>Utterbackia imbecillis</i> (paper pondshell)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
52	<i>Villosa lienosa</i> (little spectaclecase) <sup>3,4</sup>				X	X	X	X	X	X	X																	

<sup>1</sup> Federal Endangered Species (FE)

<sup>2</sup> State Rank (S1) - Critically imperiled, extremely rare, very vulnerable to extirpation, 5 or fewer occurrences

<sup>3</sup> State Rank (S2) - Imperiled in state, very rare, vulnerable to extirpation, 6 to 20 occurrences

<sup>4</sup> State Rank (S3) - Rare or uncommon in state, typically 21 to 100 viable occurrences

<sup>5</sup> State Rank (SH) - Of historical occurrence in state. May be rediscovered.

<sup>6</sup> State Rank (SNR) - Not ranked to date

<sup>7</sup> Federal Candidate Species (FC)

<sup>8</sup> State Threatened Species

<sup>9</sup> State Rank (SNA) - Not applicable - species is not a suitable target for conservation activities

TWAP-SC = Species of Concern, TPWD Texas Wildlife Action Plan 2005 - [www.tpwd.state.tx.us/publications/pwdpubs/pwd\\_pl\\_w7000\\_1187a/](http://www.tpwd.state.tx.us/publications/pwdpubs/pwd_pl_w7000_1187a/)

X - listed in this drainage in the Texas Wildlife Action Plan 2005



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December 15, 2011

Brent Courchene  
AECOM  
5757 Woodway, Suite 101 West  
Houston, TX 77057

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Carter P. Smith  
Executive Director

Dear Mr. Courchene:

Enclosed is your new Scientific Research Permit No. **SPR-1211-396**. Please review your permit for accuracy and make note of any restrictions. If additional authority is needed, you should request a permit amendment.

**As a result of recent budget considerations, the Wildlife Permits Office will communicate electronically more often than send out hard copies in the mail. This being the case, we surely appreciate your acknowledgement of this email.**

**If you have information on the location of a rare plant or animal and would like to help us build the Texas Natural Diversity Database, please contact the Wildlife Diversity Program at 512-389-8111.**

Furthermore, it is necessary for you to carry this permit when conducting authorized activities. Sub-permittees may carry a copy in lieu of the original permit. It is also advisable to carry some additional corroborative identification such as a driver's license.

**Please be sure to notify the Parks and Wildlife Department Law Enforcement Office(s) in the region(s) of your field activities by telephone not less than 24 hours nor more than 72 hours prior to collection** if collection techniques or devices being used are ordinarily classified as illegal (i.e., hunting/collection along public roads and rights-of-way; shooting game animals at night by use of light; taking game species during closed seasons; using gill nets or electro-shocking devices to collect fish, etc.). **A confirmed response from the local game warden is required prior to collection if the sampling activities being conducted involve methods of capture ordinarily classified as illegal.** If the regional office(s) or telephone number(s) is unknown, the number(s) may be obtained at any time by calling a Parks and Wildlife Communication Center: Austin - (512) 389-4848; Houston - (281) 842-8100.

**In addition, please be advised that collecting in a wildlife management area is not authorized without prior written permission from the area manager.**

Although the permit does not have to be renewed each year, annual reports are required for the permit to remain valid. Please note that all mortalities, retained and discarded, must be documented and reported on annual reports. **Your first annual report will be due in December 2012**; please use the report form provided with this permit. The report form is also available online: [www.tpwd.state.tx.us/business/permits/](http://www.tpwd.state.tx.us/business/permits/).

Please note that you will be required to obtain/hold a U.S. Fish & Wildlife Service federal permit for collection and/or handling of federally protected wildlife, including banding, possession, and/or salvage of migratory birds. Should you have any questions or require further assistance, please contact me at 512-389-4647.

Sincerely,

Christopher Maldonado  
Wildlife Permits Specialist

Enclosures

SCIENTIFIC PERMIT NUMBER SPR-1211-396  
IS HEREBY ISSUED TO:

Brent Courchene  
AECOM

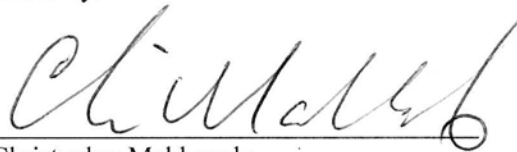
UNDER THE AUTHORITY OF CHAPTER 43, SUBCHAPTER C OF THE  
TEXAS PARKS AND WILDLIFE CODE

The activities permitted by this document are to be carried out in accordance with the Texas Parks and Wildlife Code, the Rules and Regulations of the Texas Parks and Wildlife Commission, and all of the following provisions:

1. This permit may not be transferred, assigned or conveyed by the holder.
2. The issuance of this permit is not a guarantee that a subsequent permit or renewal of this permit will be granted.
3. Required information and data shall be maintained at the address of the permit holder and shall be available for inspection at the request of personnel of the Texas Parks and Wildlife Department during the active life of the permit.
4. Acceptance of this permit constitutes an acknowledgment and agreement that the holder will comply with all Rules, Regulations, Orders and Proclamations of the Texas Parks and Wildlife Commission issued in accordance with the law and the conditions precedent to the granting of this permit. Failure to comply with any and all provisions of this permit may result in enforcement action, including any criminal penalties authorized by the Parks and Wildlife Code.
5. This permit does not relieve the holder of the responsibility to obey all other local, county, state and federal laws while carrying out the authorized activities.

- ADDITIONAL PROVISIONS FOLLOW ON ATTACHED PAGES. -

Carter Smith  
EXECUTIVE DIRECTOR  
TEXAS PARKS AND WILDLIFE DEPARTMENT  
Issued by:



Christopher Maldonado  
Wildlife Permits Specialist

**December 15, 2011**  
Effective date



6. This permit will expire at midnight, **December 15, 2014**
7. The following individuals may conduct the activities authorized by this permit under the guidance of the permittee:

**SUBPERMITTEES:** NONE

**UNPERMITTED ASSISTANTS:** A permittee engaging unpermitted assistants shall maintain on file at their office and possess on their person in the field a signed and dated list of all unpermitted persons assisting in permitted activities.

8. The following wildlife species in the specified quantities are authorized by this permit to be:

**a. SURVEY OF FRESHWATER MUSSELS.** live-captured, removed from stream for identification purposes, GPS coordinate (unbuffered) noted at all sites where state-listed mussel species were located or observed (submitted with Annual Report, preferably in an electronic – Excel format), and released unharmed at location of capture with the posterior aperture exposed. Any species encountered during this project will be handled only as much as absolutely necessary for their capture and release. Additionally, permittee is authorized voucher specimens.

Common name	Quantity
-----	
SURVEY OF FRESHWATER MUSSELS	
Freshwater Mussels	N.A.
<b>Including</b> species listed by the Department as threatened or endangered.	
VOUCHER SPECIMENS	
Freshwater Mussels (non-threatened or endangered)	NTE 5 / location
Freshwater Mussels (threatened or endangered)	NTE 1 / location
-----	

*\*In accordance with specifications listed on a valid federal permit, if applicable.*

**b. SALVAGE.** Specimens found dead. GPS coordinate (unbuffered) noted at all sites where state-listed mussel species were located or observed (submitted with Annual Report, preferably in an electronic – Excel format).

Common Name	Quantity
-----	
Mussel shells and tissue from dead mussels	N.A.

**Including** species listed by the Department as threatened or endangered.

*\*In accordance with specifications listed on a valid federal permit, if applicable.*

9. The following means for taking or capture are authorized by this permit:

**a.** Hand collection, snorkeling, SCUBA gear, and wading survey utilizing visual and tactile collecting techniques, or as specified above.

**b.** Crowfoot hooks, bars, other brail equipment, dredging, or other means of potentially harmful mass gathering is not authorized.

10. The following locations for taking or capture are authorized by this permit:

**a.** Luce Bayou (Trinity River) and Lake Houston, Texas

11. All specimens taken or salvaged shall be deposited with an appropriate collection, or otherwise disposed of in accordance with paragraph 13d of this permit.

12. **All fish collection gear left unattended shall be clearly marked with permittee's name and permit number.**

13. **PERMIT HOLDER IS REQUIRED TO:**

a. **File a completed report form annually** (provided on issuance of this permit), and any reports or publications based on data collected under authority of this permit, with the Texas Parks and Wildlife Department, Wildlife Permits Section, 4200 Smith School Rd., Austin, TX, 78744, **no later than fourteen days following the anniversary date of the permit** (or the expiration date if the permit is due for renewal).

**YOUR PERMIT WILL NOT BE VALID UNLESS YOUR REPORT HAS BEEN RECEIVED.**

b. Carry a copy of this permit at all times when exercising the provisions of this permit, which shall be subject to inspection by any authorized enforcement officer of the Department upon request.

c. **Notify the Parks and Wildlife Department Law Enforcement Office(s) in the region(s) of your field activities by telephone not less than 24 hours nor more than 72 hours prior to collection** if collection techniques or devices being used are ordinarily classified as illegal (i.e., hunting/collection along public roads and rights-of-way; shooting game animals at night by use of light; taking game species during closed seasons; using gill nets or electro-shocking devices to collect fish, etc.). **A confirmed response from the local game warden is required prior to collection if the sampling activities being conducted involve methods of capture ordinarily classified as illegal.** If the regional office(s) or telephone number(s) is unknown, the number(s) may be obtained at any time by calling a Parks and Wildlife Communication Center: Austin - (512) 389-4848; Houston - (281) 842-8100.

d. Dispose of protected wildlife taken under the authority of this permit in only one of the following ways:

(1). Kill and utilize by examination, experimentation, necropsy or dispose of as waste in accordance with state law and city or county regulations (burning is suggested if not in conflict with city, county or state regulations).

(2). Hold permanently for scientific or educational purposes, or donate to another educational display, scientific, or zoological permit holder authorized to receive such specimens, **with required specimen donation form provided by the Department. A copy of the completed form must be submitted with the annual report.**

(3). Release unharmed at collection site.

(4). Donate edible portions of game species to charitable organizations, public hospitals, orphanages or indigent persons. Arrangements for donations are the responsibility of the permit holder.

14. **PERMIT HOLDER IS PROHIBITED FROM:**

a. Selling or bartering specimens collected under the authority of this permit. Specimens may be donated to other permit holders by completing the receipt form enclosed with the permit.

b. Collecting on private premises without prior written consent of the owner or operator of the premises.

c. Collecting in a state park without prior written permission from Texas Parks and Wildlife Department Natural Resource Program: email: [david.riskind@tpwd.state.tx.us](mailto:david.riskind@tpwd.state.tx.us)

d. Collecting in a wildlife management area without prior written permission from the area manager.

e. Taking species listed by the department as threatened or endangered without express authority in paragraph 8 of this permit.

15. **ADDITIONAL PROVISIONS:**

a. No hunting or fishing license is required for permit holders or individuals listed in paragraph 7 while conducting the activities expressly authorized by this permit. Each listed individual should carry a copy of this permit during collection activities, and a letter of permission from the permittee if working independently.

b. **This permit is subject to any applicable federal permit requirements.** Where a federal permit is required, the permit holder is cautioned to carry a copy of the federal as well as the state permit during collecting activity. For information on the federal permit contact: U.S. Fish and Wildlife Service, PO Box 709, Albuquerque, NM, 87103-0709; (505)248-7882 or FW2\_Birdpermits@fws.gov. Webpage address: <http://www.permits.fws.gov/>

16. **PERMIT HOLDER'S ADDRESS FOR RECORDKEEPING PURPOSES:**

Brent Courchene  
AECOM  
5757 Woodway, Suite 101 West  
Houston, TX 77057

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## **AECOM Scientific Dive Plan**

**Dates:** January 4, 2011 through January 7, 2011  
**Project Title:** Luce Bayou Interbasin Water Transfer Project  
**Project Manager:** Ralph Calvino  
**Department:** Water  
**Phone:** (713) 267-2956  
**Address:** 5757 Woodway, Suite 101 West, Houston, Texas 77057  
**Email:** Ralph.Calvino@aecom.com  
**Purpose:** Research/Scientific –Freshwater Mussel and Habitat Characterization Assessment

### **List of Dive Team Members:**

Brent Courchene, AECOM (Lead Diver, Dive Safety Officer)

Ryan Robitaille, AECOM (Diver 1)

Ralph Calvino, AECOM (Tender)

Lyndsay Massey, AECOM (Surface Support)

Mike Mason, Coastal Water Authority (Captain)

**Location:** Trinity and San Jacinto River Basins- Liberty, Texas  
**Maximum Depth:** 20 feet  
**Total Daily Bottom Time:** 200 minutes  
**Mode:** No Decompression, Tank Supplied Air  
**Environment:** River /Stream  
**Entry:** Boat and Land based  
**Breathing Gas/Source:** Compressed Air – W W Diving Co, Humble, TX  
**Dive Tables:** US Navy/ NAUI/ Computers  
**Support Vessel:** 22' Aluminum

### **Site Specific Considerations:**

Dives will be restricted to the proposed areas for the intake and discharge locations associated with the Luce Bayou Interbasin Transfer Project, and will be monitored by a dedicated surface support staff while at depth. Currents and wave activity and river traffic is anticipated to be completely manageable, but will be monitored by surface support. Diving will not occur in Coast Guard restricted areas without prior notification. Dive efforts will consist of mussel surveys including distribution, habitat utilization, and species identification within the close proximity (~200') of the support vessel.

### **Description of Dive Protocols/Procedures:**

- Brent Courchene will review weather and water conditions in the morning of anticipated dive efforts to determine if conditions are suitable for deployment

- A pre-deployment safety and task meeting will be held with divers, support staff, and boat operators to discuss and review safe conduct of planned dive operations.
- Ralph Calvino will be the onboard observer for dives and can be contacted by the AECOM cell phone number 713-907-7304.
- Conduct dives to identify mussels and collect mussel distribution, habitat utilization, and related data according to approved procedures and work plans. Dives will be no-decompression, restricted to 30 FSW, and will not exceed 60 minutes in length.
- In the event of an emergency or accident requiring medical attention the protocols detailed in the approved Regional Scientific Diving Standard Operating Procedures and Health and Safety Plan will be adhered.
- A member of the dive team will contact Rich Renzi following daily dive operations to confirm safe dive operations.

**Emergency Contacts:****Coast Guard:**

Name: Station Galveston, Texas  
Location: 1 Ferry Road, Galveston, TX 77553  
Contact #: (409) 766-5633

**Hospital:**

Name: Liberty – Dayton Community Hospital  
Location: 1353 North Travis Street, Liberty, TX, 77575  
Contact #: 281-420-8600

**Hyperbaric Treatment Chamber:**

Name: Memorial Hermann Hospital  
Location: 7600 Beechnut, 2<sup>nd</sup> Floor, Houston, TX, 77074  
Phone: 713-456-6100

**Staff:**

Rich Renzi, NE Regional Safety Representative, AECOM  
781-224-6450, Home 1-978-475-0190

Ralph Calvino, Project Manager/ Topside dive observer, AECOM  
(713) 267-2956

Mike Mason, Captain, Coast Water Authority  
713-658-9020

Nathan Henderson, Dive Safety Officer, AECOM  
781-307-8906

**Lead Diver, Safety, and Supervisor Approval:**

<u>Brent Courchene (Lead Diver)</u>	<u>Date: 1/02/2012</u>	<u>Approved: X</u>
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<u>Rich Renzi (Health and Safety Representative)</u>	<u>Date: 1/02/2012</u>	<u>Approved: X</u>
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<u>Ralph Calvino (Project Manager)</u>	<u>Date: 1/02/2012</u>	<u>Approved: X</u>
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<u>Nathan Henderson (Dive Safety Officer)</u>	<u>Date: 1/02/2012</u>	<u>Approved: X</u>
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# LUCE BAYOU INTERBASIN TRANSFER PROJECT



## HEALTH AND SAFETY PLAN

Luce Bayou Interbasin Transfer  
Southeast Texas

Revision 1

Prepared for  
**Coastal Water Authority**  
Houston, Texas

Prepared by  
AECOM USA Group, Inc.  
April 2009  
Project No. 60097600

# Project Manager's HASP Checklist

## Before Each Mobilization

- ☐ Review the HASP for applicability to the project and make appropriate changes.
- ☐ Forward a completed copy to the Regional HS&E Manager for filing.
- ☐ Remove this page prior to issuing to field staff or subcontractors.
- ☐ Provide a copy of the HASP to the AECOM field staff.
- ☐ Provide copies to subcontractors working for AECOM on the project site.
- ☐ Confirm that all personal protective equipment specified in the HASP are available to all AECOM employees.
- ☐ Confirm that monitoring equipment specified in the HASP is available to the field staff.
- ☐ Attach Material Safety Data Sheets for all chemicals used by AECOM or subcontractors.

## After Each Demobilization

- ☐ If there is a "Stop Work Order" occurrence, submit a complete Stop Work Order (*Appendix A*) to the Health and Safety Office; place a copy in the project file.
- ☐ Collect signed HASP Acceptance Forms (*Appendix B*) for all field staff and subcontractors for project files.
- ☐ Collect copies of Pre-Entry Briefing Attendance Forms (*Appendix C*) for project files.
- ☐ Collect copies of completed Job Safety Analysis forms (*Appendix D*) for project files.
- ☐ Place a copy of the HASP in the project file.
- ☐ If an incident(s) or near-miss incident occurred, complete a Supervisor's Incident Report (*Appendix F*) and place a copy in the project file.
- ☐ If an incident(s) or near-miss incident occurred, complete initial steps of the Incident Investigation and Review Report (*Appendix G*) and coordinate with the Responsible Lead Investigator to identify the management representative responsible for conducting the remaining incident investigation.

# HEALTH AND SAFETY PLAN

## Luce Bayou Interbasin Transfer



### Southeast Texas

### Revision 1

Prepared for:

### Coastal Water Authority

Houston, Texas

Prepared By:		April 7, 2009
	David A. Dow, PE AECOM Office Safety Rep.	Date
Approved By QA Reviewer:		April 7, 2009
	RC Skaggs AECOM Regional Manager - Safety, Health and Environmental	Date

### Revision Log

Revision	Date	Author	Approvers
Original HASP	02/05/2009	D. Dow	V. Castañeda
Revision 1	04/07/2009	D. Dow	RC Skaggs

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Appendix C – Pre-Entry Briefing Attendance Form

Appendix D – Job Safety Analysis

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Appendix F – Incident Reporting

Appendix G – Incident Investigation and Review

## List of Acronyms

ACGIH	American Conference of Industrial Hygienists
FHWA	Federal Highway Administration
HASP	Health and Safety Plan
JMP	Journey Management Plan
JSA	Job Safety Analysis
MSDS	Material Safety Data Sheets
MUTCD	Manual of Uniform Traffic Control Devices
OSR	Office Safety Representative
OSHA	Occupational Safety and Health Administration
PM	Project Manager
PPE	Personal Protective Equipment
ROW	Right-of-way
RSM	Regional Safety Manager aka Regional SH&E Manager
SH&E	Safety, Health & Environmental
SOP	Standard Operating Procedure
SSO	Site Safety Officer
THA	Task Hazard Analysis

## 1.0 Emergency Information and Hazard Assessment

### Luce Bayou Interbasin Transfer, Southeast Texas

#### 1.1 Emergency References

Ambulance, Fire, Police:

911

Medical Services Locations:

Map of 1353 N Travis St, Liberty, TX 77575-3549

YAHOO! LOCAL  
Maps



**Liberty-Dayton Community Hospital (Point A)**

**City of Liberty map**

1353 N Travis St Liberty TX 77575

<http://www.libertydaytonhospital.com/>

Phone: (936) 336-7316

**Map of 1353 N Travis St, Liberty, TX 77575-3549**

**YAHOO!** LOCAL  
Maps



**Liberty-Dayton Community Hospital (Point A)**

### City of Liberty close-up map

1353 N Travis St Liberty TX 77575

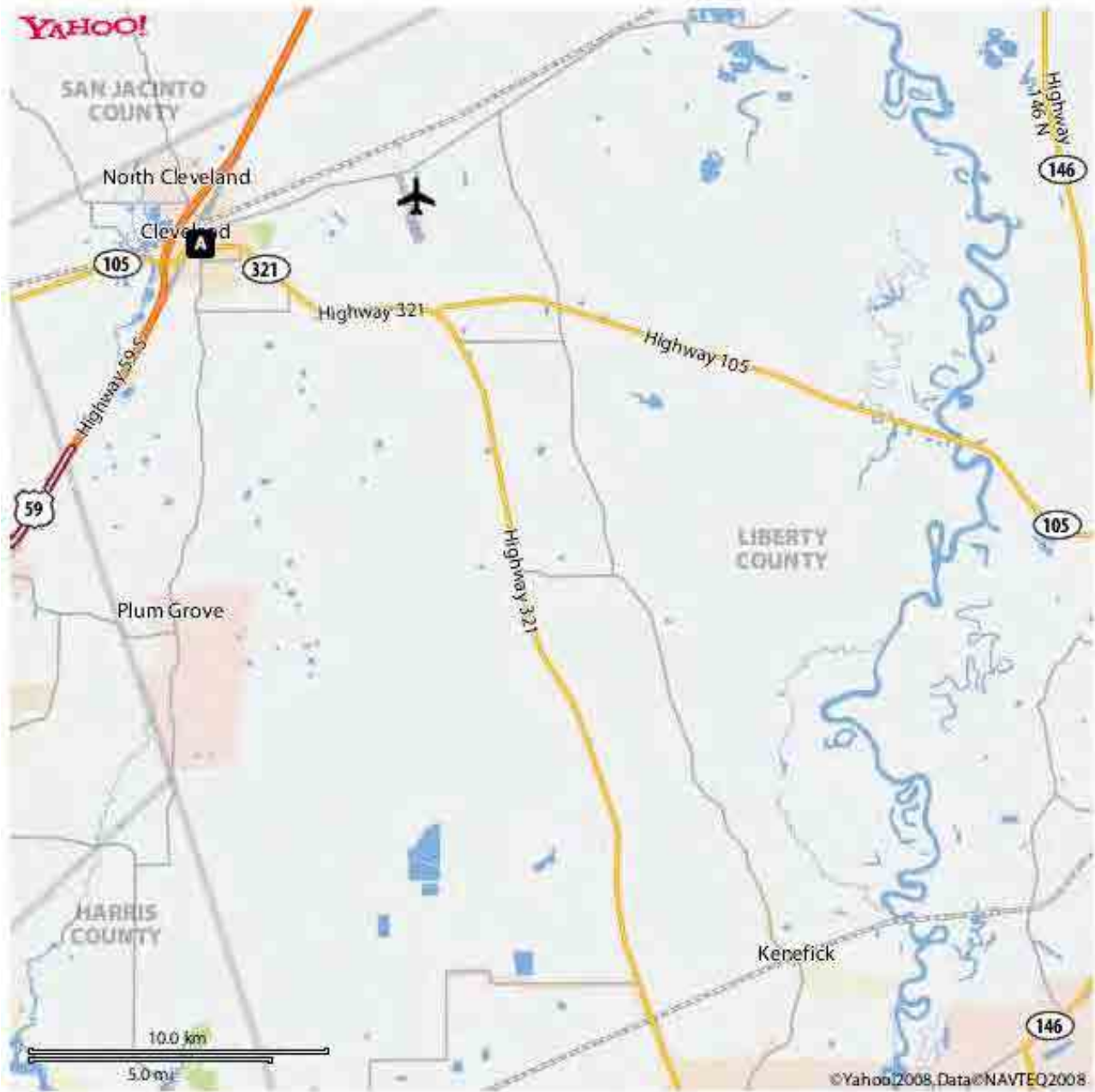
<http://www.libertydaytonhospital.com/>

Phone: (936) 336-7316

**Medical Services Locations Cont.**

**Map of Cleveland Regional Medical Center (281) 593-1811**

**YAHOO! LOCAL**  
Maps



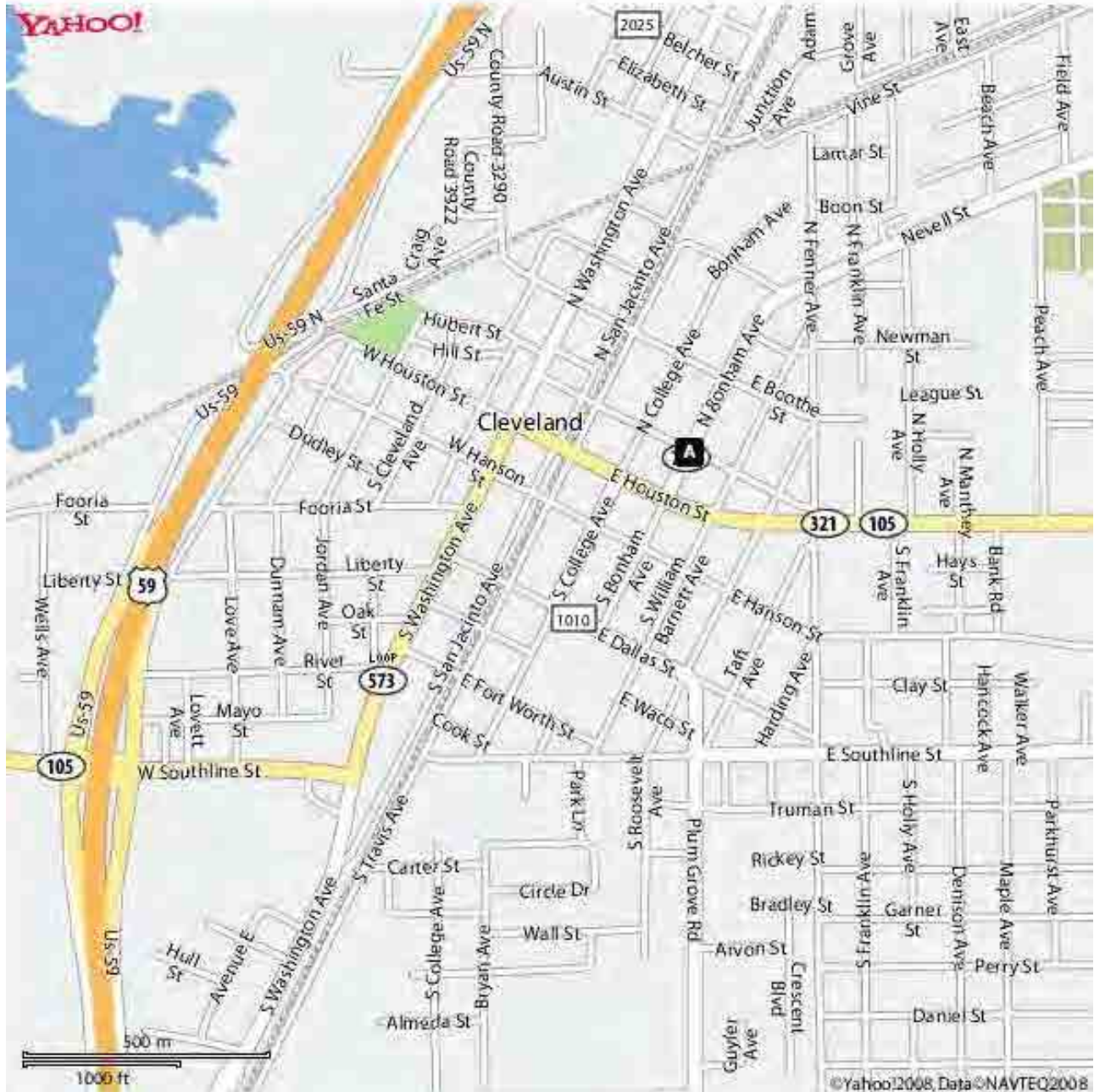
**Cleveland Regional Medical Center (Point A)**

**City of Cleveland map**

300 East Crockett, Cleveland, TX 77327

<http://www.clevelandregionalmedicalcenter.com/Pages/Home.aspx>

(281) 593-1811



(281) 593-1811

## Poison Control Center

The Texas Poison Center Network: **1-800-222-1222**

### AECOM Project Representatives:

#### Office

#### Mobile

Donald Ripley, P.E., Project Director	713-267-2853	713-679-0363
Jeff Eversberg, P.E., Project Mgr.	713-267-3299	281-851-5383
David Dow, P.E., Office Safety Rep.	713-267-3279	713-816-3259
RC Skaggs, USIG, RSM	602-337-2607	312-912-2438

## 1.2 Hazard Assessment

**Chemical Hazards:** No chemical hazards are anticipated for this project.

### Physical Hazards:

Animals	Insects	Tripping
Dust	Poisonous Plants	Weather
Falling	Sharp Objects	Working in Water
Heat	Traffic	

## 1.3 Optional Personal Protective Equipment

Prior to the field activity, the SSO will discuss any personal protective equipment (PPE) requirements.

PPE Item	See Footnote
Hard Hat	1
Traffic Vests	1
Safety Glasses with Sideshields	2
Tyvek Coveralls	3
Nitrile Gloves	3
Cotton or Leather Work Gloves	As Needed
Ivy Block® or Ivy Screen® barrier cream	4
Snake Protection	5
Sun Protection Factor Sunscreen	6

### Footnotes

1. Traffic vests and hardhats are required when working within twenty feet of any public road or any private road with active traffic. SSO will determine when long sleeve shirts are required during field activity.
2. Safety glasses with sideshields are recommended to be worn when traveling through wooded areas.
3. Tyvek coveralls or equivalent and Nitrile gloves or equivalent may be worn to protect workers from poison ivy and poison oak when contact cannot be avoided.
4. Ivy Block® or Ivy Screen® barrier cream may be worn on exposed skin where there is a potential for exposure to poison ivy or oak.
5. Snake protection (e.g., boots and snake chaps) may be worn when walking through vegetated areas where there is a potential for this matter.
6. Sun protection factor (SPF): A number on a scale for rating sunscreens. SPF numbers on a package can range from as low as 2 to as high as 60. These numbers refer to the product's ability to screen or block out the sun's burning rays. Sunscreens with an SPF of 15 or higher are generally thought to provide useful protection from the sun's harmful rays.

## **2.0 Introduction**

### **2.1 AECOM Safety Policy**

AECOM Corporation is committed to providing our employees with a safe and healthy work environment. It is not only our obligation to each other, but also a sound business practice to do so. Work related injuries and illnesses cause needless pain and suffering, cost money, and adversely affect our reputation with our clients. It is our firm belief that all work related injuries and illnesses are preventable, and it is therefore our goal to have a workplace that is free from occupational injuries and illnesses. Every attempt shall be made to eliminate the possibility of injuries and illnesses. No aspect of the company's activities, including expediency and cost, shall take precedence over the health and safety of our employees.

#### **2.1.1 Health and Safety Expectations**

Commitment to safety, health, and environmental excellence requires that all work proceed only after it is safe and environmentally sound to do so. The responsibility for ensuring that this takes place rests with every worker present at this property. Effectively meeting these responsibilities depends upon open communication between individuals and their supervisors prior to work beginning, and – in certain cases – after safety, health and/or environmental issues are identified.

The safety and health of on-site personnel will take precedence over cost and schedule considerations for all project work. All AECOM personnel have the authority to STOP WORK if they see a potential or actual hazard that may threaten the safety of people or the environment (*Appendix A, Attachment 1*). Upon stopping work, the Site Safety Officer (SSO) must be immediately notified and provided with information regarding the nature of the safety, health, or environmental concern. The SSO will meet with the worker with the intent of resolving the worker's concerns. Once the concerns are resolved to the satisfaction of the worker, work can proceed.

If the concerns are not resolved to the satisfaction of the worker and/or the SSO, work does not proceed. The AECOM Regional Safety Manager (RSM) will be contacted to obtain assistance in resolving the concerns. Using his/her expertise, safety, health, and environmental rules, regulations, and procedures, the AECOM RSM will attempt to resolve the matter with all parties involved. Work will not resume until this criterion is met.

#### **2.1.2 Maximum Duration of the Work Day for Field Activities**

An employee may not work a shift that exceeds 16 hours in duration. For the purpose of this policy, the work shift includes time spent at lunch and on break. If an employee works more than one shift during the course of a calendar day, the total number of hours worked in that day cannot exceed 16 hours.

## **2.2 Health and Safety Plan (HASP)**

### **2.2.1 HASP Purpose**

The purpose of this HASP is to identify hazards associated with this project and specify engineering and administrative controls and personal protective equipment necessary to mitigate the risks associated with these hazards. This HASP addresses the hazards recognized prior to writing or updating the documents. As new hazards are encountered, a Job Hazard Assessment (JHA) or Job Safety Analysis (JSA) must be conducted and the results input into the HASP.

This HASP also assigns responsibilities for the implementation of safety programs on this project and defines monitoring and emergency response planning specific to the project.

### **2.2.2 HASP Applicability**

This site-specific HASP has been developed by AECOM Corporation (AECOM). It establishes the health and safety procedures required to minimize potential risk to AECOM and contractor personnel involved with the

environmental investigations, surveying, site visits, and other field activity associated with the Luce Bayou Interbasin Transfer Project.

Client, subcontractor, and visiting personnel who will not be exposed to hazards on the site do not need to meet the training and personal protective equipment requirements of this HASP as long as they are escorted at all times by a fully trained and qualified person with knowledge of all hazards on the site. Such unqualified people can include surveyors, utility locators, government personnel, AECOM and Client representatives, and others with business reasons to be at the site. Medical surveillance of personnel is assumed not required.

The provisions of this plan apply to AECOM and AECOM subcontractor personnel who will potentially be exposed to safety and/or health hazards related to activities described in *Section 4* of this document.

This HASP has been written to comply with the requirements of the Occupational Safety and Health Administration (OSHA) Personal Protective Equipment Standard (29 CFR 1910.132) for all activities. All activities covered by this HASP must be conducted in complete compliance with this HASP and with all applicable federal, state, and local health and safety regulations. Personnel covered by this HASP who cannot or will not comply will be excluded from site activities.

This plan will be distributed to each employee involved with the proposed activities at the site, including subcontractor employees where the subcontractor has not developed their own HASP. Each employee must sign a copy of the attached Health and Safety Plan Acceptance Form (see *Appendix B*).

This HASP only pertains to the tasks that are listed in *Section 4*. A task-specific HASP or addendum to this HASP will be developed at a later date for any other subsequent investigative/remedial activities at the site.

## **2.3 Organization/Responsibility**

The implementation of health and safety at this project location will be the shared responsibility of the AECOM Project Manager (PM), the AECOM OSP, the AECOM Project SSO and other AECOM personnel and AECOM's contractors implementing the proposed scope of work.

### **2.3.1 AECOM Project Manager**

The AECOM PM (Jeff Eversberg) is the individual who has the primary responsibility for ensuring the overall health and safety of this project. As such, the PM is responsible for ensuring that the requirements of this HASP are implemented. Some of the PM's specific responsibilities include:

- Assuring that all personnel to whom this HASP applies, including AECOM subcontractors, have received a copy of it.
- Providing the Office Safety Representative (OSR) with updated information regarding conditions at the site and the scope of site work.
- Providing adequate authority and resources to the on-site SSO to allow for the successful implementation of all necessary safety procedures.
- Supporting the decisions made by the SSO and OSR.
- Maintaining regular communications with the SSO and, if necessary, the OSR.
- Coordinating the activities of all AECOM subcontractors and ensuring that they are aware of the pertinent health and safety requirements for this project.
- Conducting random project audits.

### 2.3.2 AECOM Office Safety Representative (OSR)

The AECOM OSR (David Dow) is the individual responsible for the preparation, interpretation, and modification of this HASP. Modifications to this HASP that might result in less stringent precautions cannot be undertaken by the PM or the SSO without the approval of the OSR. Specific duties of the OSR include:

- Writing, approving and amending the HASP for this project.
- Advising the PM and SSO on matters relating to health and safety on this site.
- Recommending appropriate personal protective equipment (PPE) and respiratory equipment to protect personnel from potential site hazards.
- Facilitating incident investigations.
- Maintaining regular contact with the PM and SSO to evaluate site conditions and new information that might require modifications to the HASP.
- Conducting random project audits.

### 2.3.3 AECOM Site Safety Officer

All AECOM field technicians are responsible for implementing the safety requirements specified in this HASP. However, one field technician will serve as the SSO although he/she may change daily. The SSO, and if required an assistant, will be appointed by the PM. The SSO will be on-site during all activities covered by this HASP. The SSO is responsible for enforcing the requirements of this HASP once work begins. The SSO has the authority to immediately correct all situations where noncompliance with this HASP is noted and to immediately stop work in cases where an immediate danger is perceived. Some of the SSO's specific responsibilities include:

- Assuring that all personnel to whom this HASP applies, including all subcontractors, have reviewed this HASP, and submitted a completed copy of the HASP Acceptance Form (*Appendix B*).
- Assuring that all personnel to whom this HASP applies have attended a pre-entry briefing and any subsequent safety meetings that are conducted during the implementation of the program.
- Conducting the pre-entry briefing prior to beginning work and subsequent safety meetings as necessary, using the Pre-Entry Briefing Attendance Form (*Appendix C*).
- Maintaining a high level of health and safety consciousness among employees implementing the proposed investigative activities.
- Procuring and distributing the PPE and safety equipment needed for this project for AECOM employees.
- Verifying that all PPE and health and safety equipment used by AECOM is in good working order.
- Verifying that AECOM contractors are prepared with the PPE and safety equipment required for this program.
- Preparing an initial Job Safety Analysis (JSA) during the initial mobilization and revising the Job Safety Analysis if conditions or tasks change and communicating with all workers the results of the Job Safety Analysis. See *Appendix D* for a JSA form. The JSA will be reviewed daily by all workers and updated as needed.
- Notifying the PM of all noncompliance situations and stopping work in the event that an immediate danger situation is perceived. See *Appendix A*.
- Monitoring and controlling the safety performance of all personnel within the established restricted areas to ensure that required safety and health procedures are being followed.

- Initiating emergency response procedures in accordance with *Section 12* of this HASP and coordinate all incidents to the Incident Reporting Hotline Number provided in *Appendix E*.
- Conducting accident/incident investigations and preparing accident/incident investigation reports using the Incident Reporting (*Appendix F*) and Incident Investigation and Review (*Appendix G*).

#### **2.3.4 AECOM Field Personnel**

All AECOM field personnel covered by this HASP are responsible for following the health and safety procedures specified in this HASP and for performing their work in a safe and responsible manner. Some of the specific responsibilities of the field personnel are as follows:

- Assessing each task for hazards and necessary precautions prior to beginning work on that task.
- Assessing the work area for changing conditions and new hazards and address the hazards.
- Stopping work and initiating corrective actions if work site hazards create unacceptable risk.
- Reading this HASP in its entirety prior to the start of on-site work.
- Submitting a completed HASP Acceptance Form (*Appendix B*) to the AECOM SSO prior to the start of work.
- Attending the required pre-entry briefing prior to beginning on-site work and any subsequent safety meetings that are conducted during the implementation of the program.
- Bringing forth any questions or concerns regarding the content of the HASP to the PM or the SSO prior to the start of work.
- Reporting all incidents, injuries and illnesses, regardless of their severity, to the AECOM SSO.
- Complying with the requirements of this HASP and the requests of the SSO.
- Creating a “Buddy System” whereby staff must have communication capabilities either verbally, by cell phone, or by hand held radio with at least one other staff member or a contractor.

#### **2.3.5 Contractors**

Additionally, contractors hired by AECOM are responsible for:

- Reading the HASP in its entirety prior to the start of on-site work.
- Attending the required pre-entry briefing prior to beginning on-site work and any subsequent safety meetings that are conducted during the implementation of the program.
- Ensuring that their equipment is in good working order via daily inspections.
- Operating their equipment in a safe manner.
- Appointing an on-site safety coordinator to interface with the AECOM SSO.
- Providing all the required PPE, respiratory equipment and safety supplies to their employees.
- Creating a “Buddy System” whereby staff must have communication capabilities either verbally, by cell phone, or by hand held radio with at least one other contract member or an AECOM staff member.

### **2.4 Management of Change/Modification of the HASP**

#### **2.4.1 Management of Change**

This document discusses the physical hazards associated with the proposed activities. However, unanticipated site-specific conditions or situations might occur during the implementation of this project. Also, AECOM and/or the contractors may elect to perform certain tasks in a manner that is different from what was originally intended

due to a change in field conditions. As such, this HASP must be considered a working document that is subject to change to meet the needs of this dynamic project.

### **2.4.2 Job Safety Analysis (JSA)**

AECOM and/or AECOM's contractors will complete a Job Safety Analysis (JSA) when new tasks or different investigative techniques not addressed in the HASP are proposed. The use of new techniques will be reviewed and if new hazards are associated with the proposed changes, they will be documented on the JSA form. An effective control measure must also be identified for each new hazard. JSA forms will be reviewed by the SSO prior to being implemented. Once approved, the completed forms will be reviewed with all field staff during the scheduled safety meetings. A blank JSA form is presented as *Appendix D*.

### **2.4.3 HASP Modification**

Should significant information become available regarding potential on-site hazards, it will be necessary to modify this HASP. All proposed modifications to this HASP must be reviewed and approved by the AECOM OSR before such modifications are implemented. Any significant modifications must be incorporated into the written document as addenda, and the HASP must be reissued. The AECOM PM will ensure that all personnel covered by this HASP receive copies of all issued addenda. Sign-off forms will accompany each addendum and must be signed by all personnel covered by the addendum. Sign-off forms will be submitted to the AECOM PM. The HASP addenda should be distributed during the daily safety meeting so that they can be reviewed and discussed. Attendance forms will be collected during the meeting.

## **3.0 Site Description and History**

### **3.1 Site Description**

The Luce Bayou Interbasin Transfer line begins north of Liberty, Texas, from the proposed Capers Ridge Pump Station at Trinity River and proceeds approximately 20 miles southwesterly to the northeastern shoreline of Lake Houston, Texas.

## **4.0 Scope of Work**

### **4.1 Field Tasks**

The Scope of Work includes performing field tasks such as surveying, clearing of right-of-way (ROW), operation of off-road vehicles, site visits, and other field activities. In addition, there will be environmental investigations and jurisdictional delineations of waters of the United States, including wetlands and other special aquatic sites, i.e., riffle/pool complexes, mud flats, and vegetated shallows within the proposed ROW.

## **5.0 Chemical Hazard Assessment and Control**

No chemical hazards are anticipated for this project.

### **5.1 Dust**

Dust created by agricultural, traffic, and weather can be hazardous to the respiratory system and irritating to the eyes. The ACGIH (American Conference of Industrial Hygienists) has established an eight-hour exposure limit

for respirable (particles small enough to enter the lungs) dust at 3 mg/M<sup>3</sup>. If dusts become irritating, respirators should be donned as discussed in *Section 8*. See respirator examples on website <http://store.pksafety.net/dustmasks.html>.

## 6.0 Physical Hazards and Controls

### 6.1 Hand Safety

#### 6.1.1 Glove Selection:

When increased heat stress is not an issue, synthetic, cotton, or leather gloves should be used when moving through brush or trees.

#### 6.1.2 Knives

- Always perform a thorough JSA to define the proper cutting tool and techniques for the task.
- Always place the item to be cut on a solid surface, attempt to hold the cut item without your hand, and cut in a direction away from the body and hand.
- Always keep hands and body clear of the knife stroke. Always keep the cutting tool blades sharp.
- Make sure there is plenty of open space around you when using any cutting tool.

#### 6.1.3 Machete

- Stand at least six feet from the nearest person when using a machete.
- Keep machete sharp.
- Store in a safe place.
- Always cut at an angle, never 90° to the object being cut.
- Handle should be dry and clean of foreign matter.
- Do not run with a machete in your hand.
- Do not throw a machete.
- Use sheath for securing machete.
- Always file away from the cutting edge when sharpening.

### 6.2 Lifting, Moving Objects

- Serious strains often result from improper handling of boxes and bundles, office supplies, ledgers, office machines, etc. Such objects shall be removed with a hand truck or unpacked and handled in smaller parcels.
- Bulky objects shall be carried in such a way as not to obstruct the view ahead or interfere with the use of handrails on stairways.

### 6.3 Traffic Safety

#### Basic Procedures

To make certain that motorists are aware of our presence, all employees who are potentially exposed to traffic hazards must **wear orange or yellow ANSI Class II or III safety vests**. Work area must be delineated with traffic cones, or other suitable warning barriers, to prevent motorists from inadvertently driving through. As for

vests, cones or other barrier materials must be reflectorized if work will be performed during dusk or evening hours. Where it is not feasible to implement such procedures, a standby observer will be assigned to warn the work crew of any impending traffic hazards.

### **Work On/Adjacent to Public Roadways**

For projects that involve potential exposure to traffic on or adjacent to public roadways, consult the "**Work Zone Traffic Control**" handbook, under "Traffic Control" on AECOM's H&S Website, at the following web address: <http://intranet.AECOM.com/healthweb>.

The handbook was developed by the State of Maine DOT and provides examples of traffic control applications for typical road work situations (e.g., closure of one lane of a two-lane road, stationary work on the shoulder of a road, mobile work along the shoulder of a road, etc.). Although it was written to reflect the basic requirements of Part VI of the *Federal Highway Administration's (FHWA) Manual of Uniform Traffic Control Devices (MUTCD)*, this handbook is not a regulatory document. Specific requirements will vary from state to state, and within a state, by county, city or town.

## **6.4 Driving Safety**

Drivers must be (1) licensed to drive the class of vehicle they are operating and (2) trained in defensive driving. Only AECOM personnel may drive AECOM vehicles or vehicles rented for AECOM business; client, subcontractor, or other work-related personnel may ride. Drivers and passengers must comply with all traffic laws and posted signs and will not operate a vehicle if under the influence of impairing medication, alcohol, or any other substance.

### **Planning Preparation**

- Prior to departure, check traffic reports, weather conditions, road construction, and road closures. If necessary, develop an alternate route and new, approved JMP (Journey Management Plan).
- Prior to entering the vehicle, inspect the vehicle.
- Leave early to allow for contingencies.

### **Distractions**

You must NOT operate a vehicle while texting or talking on your cell phone, regardless of "hands free" or not. If you receive a call or a text message, pull over to answer it. Do NOT allow other distractions to interfere with your safe operation of the vehicle.

### **Secure Parking**

Do not move your vehicle unless all equipment and supplies are secured. Items and material which may roll, slide, or move about in your vehicle while traveling are a major hazard. Secure the load!




### **Emergency Procedures:**

Always move out of traffic if possible; even if those in front of you have stopped. Stopping on an active highway can precipitate being hit from the rear. If you must stop on an active roadway, leave at least one car length in front of you, and watch the rear mirror, so you can ease up if someone behind can't stop. Keep your flashers on in this situation. If you are the only driver coming to a stop on an active roadway, leave the flashers on and when safe to do so, exit the car and get to a safe location.

If you must stop due to vehicle failure, etc. try to coast out of traffic. Put on your flashers, and tie a white handkerchief, etc. on the driver's side door or mirror. If you remain in the vehicle, lock the doors. Use your cell phone to summon help.

## 6.5 Poisonous Plants

All undeveloped property potentially has poison ivy, oak, or sumac growing in areas where vegetation is not controlled. These plants can also be found in cultivated and landscaped areas.

<p><u>Poison Ivy</u> Grows in West, Midwest, Texas, and East. Several forms – vine, trailing shrub, or shrub. Three leaflets (can vary 3-9). Leaves green in summer, red in fall. Yellow or green flowers. White berries.</p>	
<p><u>Poison Oak</u> Grows in the East (NJ to Texas), Pacific Coast. 6-foot tall shrubs or long vines. Oak-like leaves, clusters of three. Yellow berries.</p>	
<p><u>Poison Sumac</u> Grows in boggy areas, especially in the Southwest and Northern states. Shrub up to 15 feet tall. Seven to 13 smooth-edged leaflets. Glossy pale yellow or cream-colored berries.</p>	

If you must enter areas containing such plants, it is recommended that protective clothing be worn such as Tyvek® coveralls, Nitrile or latex gloves, and boot covers. The use of a barrier cream such as Ivy Block can prevent the active agent in poisonous plants from affecting skin, and Tecnu cleansing wipes can remove the plant oil from exposed skin.

Avoid using mowers and weed trimmers in areas where poison ivy and oak are likely. Additional care should be taken during early winter after the leaves have fallen from the poisonous plants; the poison still exists in the vines and stubble remaining above the ground. Wash any contaminated skin immediately with cold water and mild soap.

## 6.6 Plants

This site is known to have plants with thorns and seeds with burrs. When working at ground level and when removing boots, look for thorns and burrs and remove them from boots and clothing with tweezers. If possible, place a plastic sheet on the ground as a working surface to prevent contacting thorns and burrs.

## 6.7 Insects

Spiders and wasps may be found in derelict buildings, sheltered areas, and even on open ground. Exercise care when collecting samples and avoid reaching into areas where visibility is limited. If stung by a wasp or bee, or bitten by a spider, notify a co-worker or someone who can help should you have an allergic reaction. If possible capture or identify the spider or insect. Stay calm and treat the area with ice or cold water. Seek medical attention if you have any reactions to the sting such as developing a rash, excessive swelling, or pain at the site of the bite or sting or any swelling or numbness beyond the site of the bite or sting.

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### **Black Widow Spider**

Abdomen usually shows hourglass marking.

The female is 3-4 centimeters in diameter.

Have been found in well casings and flush-mount covers.

Not aggressive, but more likely to bite if guarding eggs.

Light, local swelling and reddening of the bite are early signs of a bite, followed by intense muscular pain, rigidity of the abdomen and legs, difficulty breathing, and nausea.

If bitten, see physician as soon as possible.



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### **Brown Spiders (Recluse)**

Central and South U.S., although in some other areas, as well.

¼- to ½-inch-long body and size of silver dollar.

Hide in baseboards, ceiling cracks, and undisturbed piles of material.

Bite either may go unnoticed or may be followed by a severe localized reaction, including scabbing, necrosis of affected tissue, and very slow healing.

If bitten, see physician as soon as possible.



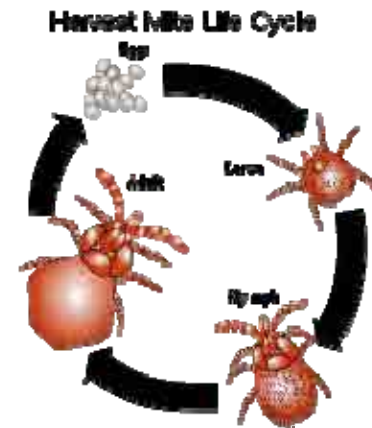
## Scorpions

All scorpion species possess poison or venom. Scorpions use their venom to kill or paralyze their prey so that it can be eaten; in general it is fast-acting, allowing for effective prey capture. Scorpions are relatively timid creatures which are preyed on by a variety of larger predators, most of which can easily outmaneuver the scorpion and tear off its stinger. Thus, when confronted by a larger creature, scorpions will generally run for the nearest cover.

Of the ~1500 scorpion species, the vast majority are only capable of producing a local reaction similar in scope and effect to a [bee sting](#). Scorpions rarely aggressively attack humans, but will often reflexively strike when they are handled, stepped on in bare feet, or accidentally crushed in clothing. Their ubiquity in certain rural areas and nocturnal, cold-blooded physiology often result in scorpions making their day burrows in human objects or dwellings. Footwear or clothing left outside overnight, thatched roofs, cracks in plaster or concrete, and wood and brush piles are all common shelter sites for scorpions.



**Harvest mites** (also known as *red bugs*, *trombiculid mites*, *scrub-itch mites*, *berry bugs* or, in their [larval](#) stage, as *chiggers* or *chigoe*) make up a genus of [mites](#) in the family [Trombiculidae](#) that live in forests and grasslands and are also found in low, damp areas where vegetation is rank such as [woodlands](#), berry patches, [orchards](#), along lakes and streams, and even in drier places where vegetation is low such as lawns, golf courses, and parks. They are most numerous in early summer when grass, weeds and other vegetation are heaviest. In their larval stage they attach to various animals, including humans, and feed on skin, often causing itching.



### African Honey Bee

The African honey bee is a [subspecies](#) of the [Western honey bee](#). It is native to central and southern Africa, though at the southern extreme it is replaced by the [Cape honey bee](#), *Apis mellifera capensis*.

This subspecies has been determined to constitute one part of the ancestry of the [Africanized bees](#) (AKA "killer bees") spreading through the [Americas](#).

A single African bee sting is no more venomous than a single European bee sting. Africanized honeybees respond more quickly when disturbed than do EHBs. They send out three to four times as many workers in response to a threat. They will also pursue an intruder for a greater distance from the hive.

Inappropriately labeled "killer bees", the sting of the AHB is no more venomous than that of the EHB. Each bee delivers only one sting. AHB are more aggressive and more bees deliver stings than EHB, resulting in more venom. Although people have died as a result of 100-300 stings, it has been estimated that the average lethal dose for an adult is 500-1,100 bee stings.



### Wasps

A **wasp** is a [predatory](#) flying stinging [insect](#) of the order [Hymenoptera](#) and suborder [Apocrita](#) that is neither a [bee](#) nor an [ant](#). A narrower and simpler but popular definition of the term **wasp** is any member of the aculeate family [Vespidae](#). Wasps are critically important in natural [biocontrol](#) as almost every pest insect species has at least one wasp species that is a predator upon it. Parasitic wasps are increasingly used in agricultural [pest control](#) as they have little impact on crops.



## Ticks

**Tick** is the common name for the small [arachnids](#) in [superfamily Ixodoidea](#) that, along with other [mites](#), constitute the [Acarina](#). Ticks are [ectoparasites](#) (external parasites), living by [hematophagy](#) on the [blood](#) of [mammals](#), [birds](#), and occasionally [reptiles](#) and [amphibians](#). Ticks are important [vectors](#) of a number of diseases, including [Lyme disease](#) and [Tick-borne meningoencephalitis](#).

Young ticks have six legs, and mature ticks have eight legs. They are about the size of a sesame seed, and males are black; females have a brick-red abdomen with a black shield-like plate close to their head.

Ticks are blood-feeding parasites that are often found in tall [grass](#) and shrubs where they will wait to attach to a passing host. Physical contact is the only method of transportation for ticks. Ticks do not jump or fly, although they may drop from their perch and fall onto a host. Some species actively stalk the host by foot.

Changes in temperature and day length are some of the factors signaling a tick to seek a host. Ticks can detect heat emitted or carbon dioxide respired from a nearby host. They will generally drop off the animal when full, but this may take several days. In some cases, ticks will live for some time on the blood of an animal.

Ticks can be found in most wooded or forested areas throughout the world. They are especially common in areas where there are [deer](#) trails or horse paths.

Some of the more common diseases that can be contracted from a tick bite include: [Babesiosis](#), [Ehrlichiosis](#), [Lyme disease](#), [Rocky Mountain spotted fever](#), Southern tick-associated rash illness, Tick-borne relapsing fever, and [Tularemia](#).

To control ticks outdoors so they don't get transmitted inside, you can use liquid spray using a hand sprayer or a hand spreader. Using the amount instructed on the label for liquid spray and granule.



Engorged deer tick attached to back of toddler's head. Adult thumb shown for scale.



Male tick size comparison to a match.

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**Fire ants**, are stinging ants with over 280 species worldwide. The venom of a fire ant sting causes stinging and swells into a bump. This can cause much pain and irritation at times, especially when stung repeatedly by several at once. The bump often forms into a white pustule, which is at risk of becoming infected if scratched; however, if left alone, usually goes down within a few days. The pustules are unattractive and uncomfortable while active and, if the sting sites become infected, can turn into scars. Additionally, some people are allergic to the venom and, as with many allergies, may experience anaphylaxis, which requires emergency treatment. An antihistamine or topical corticosteroids may help reduce the itching.



First aid for fire ant bites includes external treatments and oral medicines.

External treatments: a topical steroid cream (hydrocortisone), or one containing aloe vera.

Oral medicines: antihistamines.

Patients who experience severe or life threatening allergic reactions to fire ant insect stings should visit a doctor or hospital immediately upon contact as these reactions can result in death. These more severe reactions include severe chest pain, nausea, severe sweating, loss of breath, serious swelling, or slurred speech.

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Studies have determined that repellants containing DEET as a main ingredient are most effective against spiders, mosquitoes, and other insects. DEET can be directly applied to the exposed skin of adults and/or clothing. Permanone® is another repellent; however, it can only be directly applied to clothing.

## 6.8 Mammals

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**Feral Hogs:** All wild animals have the potential of being dangerous, especially when wounded or cornered. In a natural state, feral hogs will prefer to run and escape danger, and are not considered dangerous. Extreme caution should be maintained when tracking wounded animals, trapping animals or encountering females with young. Their razor sharp tusks combined with their lightning speed can cause serious injury.



If the hog(s) approaches, make yourself look big by opening your jacket and holding the left and right parts out to the side of your body. Carry a bottle of pepper spray and know how to use it. Use these methods for threatening **dogs** too.



## 6.9 Alligators

Alligators are known to be present in the ponds and wetland areas. When working within 100 feet of surface waters assume that you are in the presence of alligators. Alligators six feet or larger present the greatest hazard. Smaller alligators, four feet or less, pose little threat to people, but a bite from any alligator could result in serious infection. Regardless of how minor a bite appears, it would be wise to consult a physician immediately.



- Always be aware of what is around you to avoid unexpected encounters.
- Under no circumstances should you approach an alligator closely. They are quite agile, even on land. As with any wild animal, alligators merit a measure of respect.
- During mating season, male alligators can be very aggressive toward other males or toward humans. Mated pairs are frequently seen swimming or sunning together by mid-May; the male is the larger of the two.
- An alligator nest is a pile of rotting grass, other vegetation and mud. The pile is 3 1/2 to 6 feet across and 1 to 2 feet high, sitting in a site 13 to 18 feet across that has been cleared of vegetation. The female alligator stays close to guard the eggs from raiding raccoons, skunks and opossums. After the eggs hatch in late summer, the pod of baby alligators will stay together through their first winter and often through their second winter as well. The mother alligator stays close to her pod of babies, protecting them from male alligators, herons and humans.



## 6.10 Snakes

Venomous snakes can be encountered on or near the ROW. Use the same precautions discussed regarding spiders and wasps (*Section 6.6*). Sturdy boots covering the ankle should be worn in open terrain. Snake boots and snake chaps may be worn when walking or working in heavily vegetated areas, wet lands, or areas covered with large amounts of debris. SSO or OSR will have ultimate decision on what to wear.

If bitten, stay calm and seek help. Do NOT cut the bite area, but use a snakebite kit if available. Try to be able to identify the snake to medical personnel. Remember that bites of non-venomous snakes can become infected. Get medical attention for any animal bite.

The following photos provide an illustration of common poisonous snakes found in Liberty and Harris Counties. A list of common non venomous snakes is provided. Those working in the field should never attempt to handle snakes.

## **Venomous Snakes**

**Texas Coral Snake**



**Southern Copperhead**



**Timber Rattlesnake**



**Cottonmouth**



**Western Pigmy Rattlesnake**



## 6.11 Water Hazards

AECOM employees will not enter standing or flowing water deeper than three feet unless they are tethered to a stationary object located at least ten feet from the edge of the water. In all cases employees entering surface water will wear personal flotation devices and a second person will be stationed on the shore to assist during emergencies. Do not enter water unless you know the maximum depth in the area you are working.

Note that the water can contain bacteria and fungal organisms that can cause skin and internal infections. Employees should avoid direct contact with the water. If splashing water is produced during the operations, employees may consider wearing face shields and or aprons.

## 6.12 Weather

The SSO will check the weather forecast for the project area each morning prior to mobilization. Predicted weather conditions will be included in the JSA with changes in the weather necessitating an update of the JSA, as necessary. Severe weather can occur with little warning. The employee must be aware of the potentials for lightning, flash flooding and high wind events.

### Be Prepared, Know What is Coming Your Way

- Listen to the radio for severe weather alerts.
- Check the Storm Prediction Center's web page <http://www.spc.noaa.gov/products/wwa/>, for alerts and warnings.
- Pay attention to the weather in your area, upwind of your location and in the watershed upstream from your location.
- When in the field, be aware of the route you must take to get to shelter.
- When working in low areas, be aware of the potential for flash flooding and the route to higher ground.

### 6.12.1 Lightning

Lightning can strike up to a distance of 10 miles from the source cloud, but thunder can only be heard at a distance of 8 miles. Therefore, if site personnel working outdoors hear thunder and/or see lightning, work will be stopped and personnel will move to an indoor location.

If a storm comes up suddenly and you are outdoors, seek the best shelter you can find. If choosing between a building and a car, choose the building. If you're in a car, keep the windows closed. If there is no shelter, find a low lying, open place that is a safe distance from trees, poles or metal objects that can conduct electricity. Make sure it is an area that is not likely to flood! Remember, lightning does not necessarily strike the tallest object; it will strike the best conductor on the ground which might be a human being. Assume a tucked position and squat low to the ground. Place your hands on your knees with your head tucked between them. Try to touch as little of your body to the ground as possible and keep your feet touching each other. If you feel your hair stand on end in a storm, drop into a tucked position immediately. This sensation means electric charges are already rushing up your body from the ground toward an electrically charged cloud.

Work will resume 30 minutes following the final observance of thunder and/or lightning.

### 6.12.2 Tornadoes and High Wind

#### Outdoors:

Abandon vehicles and temporary buildings. A tornado can move faster than you can drive.

**Find shelter!** The danger in a tornado or high winds is flying debris including trees, vehicles, and temporary buildings.

Find shelter in a ditch or other location that will protect you from winds coming from all directions. Bridges and overpasses offer little protection and should be the last choice for shelter; the space where the bridge abutment and the bridge meet is better than no shelter on open ground.

#### **Indoors:**

Get as many walls between you and the storm as you can, if you can see a window you are not in a shelter.

- Interior restrooms, stairwells, and closets offer protection.
- Basements and underground shelters offer the best protection.

Never watch a nearby tornado either outside or through a window. Large tornadoes can blow airborne debris up to a mile from the funnel.

### **6.12.3 Heat Stress**

#### Types of Heat Stress

Heat-related problems include **heat rash, fainting, heat cramps, heat exhaustion, and heat stroke**. **Heat rash** can occur when sweat isn't allowed to evaporate; leaving the skin wet most of the time and making it subject to irritation. **Fainting** may occur when blood pools to lower parts of the body and as a result, does not return to the heart to be pumped to the brain. Heat-related fainting often occurs during activities that require standing erect and immobile in the heat for long periods of time. **Heat cramps** are painful spasms of the muscles due to excessive salt loss associated with profuse sweating.

**Heat exhaustion** results from the loss of large amounts of fluid and excessive loss of salt from profuse sweating. The skin will be clammy and moist and the affected individual may exhibit giddiness, nausea, and headache.

**Heat stroke** occurs when the body's temperature regulatory system has failed. The skin is hot, dry, red, and spotted. The affected person may be mentally confused and delirious. Convulsions could occur. **EARLY RECOGNITION AND TREATMENT OF HEAT STROKE ARE THE ONLY MEANS OF PREVENTING BRAIN DAMAGE OR DEATH.** A person exhibiting signs of heat stroke should be removed from the work area to a shaded area. The person should be soaked with water to promote evaporation. Fan the person's body to increase cooling.

Increased body temperature and physical discomfort also promote irritability and a decreased attention to the performance of hazardous tasks.

#### *Early Symptoms of Heat-Related Health Problems:*

Decline in Task Performance	Excessive fatigue and irritability
Reduced Vigilance	Dizziness
Unsteady Walk	Incoordination – due to dehydration nerve synapses stop carrying normal electrical impulses, so arms and legs don't behave as normal, e.g., like being drunk
Decline in Alertness	Muscle Cramps

*Susceptibility to Heat Stress Increases due to:*

Lack of physical fitness	Obesity
Lack of acclimatization	Drug or alcohol use
Increased age	Sunburn
Dehydration	Infection

People unaccustomed to heat are particularly susceptible to heat fatigue. First-timers in PPE need to gradually adjust to the heat.

The Effect of Personal Protective Equipment

Sweating normally cools the body as moisture is removed from the skin by evaporation. However, the wearing of certain PPE, particularly chemical protective coveralls (e.g., Tyvek), reduces the body's ability to evaporate, sweat and thereby regulate heat buildup. The body's efforts to maintain an acceptable temperature can therefore, become significantly impaired by the wearing of PPE.

Measures to Avoid Heat Stress:

The following guidelines should be adhered to when working in hot environments:

- Establish work-rest cycles (short and frequent are more beneficial than long and seldom).
- Identify a shaded, cool rest area.
- Rotate personnel, alternate job functions.
- Water intake should exceed sweat produced. Most workers exposed to hot conditions drink less fluids than needed because of an insufficient thirst. **DO NOT DEPEND ON THIRST TO SIGNAL WHEN AND HOW MUCH TO DRINK.** Consume enough liquid to force urination every two hours. In humid climates ice water or ice should be consumed to help maintain normal body temperature since evaporation does not provide an efficient mechanism for heat removal.
- Eat light meals before and during work shifts. Avoid highly salted foods.
- Drink sports drinks such as Gatorade® diluted 1:1 with water.
- Save most strenuous tasks for non-peak heat hours such as the early morning or at night.
- Avoid alcohol during prolonged periods of heat. Alcohol will cause additional dehydration.
- Avoid double shifts and/or overtime.

The implementation and enforcement of the above-mentioned measures will be the joint responsibility of the PM and the SSO. Potable water and fruit juices should be made available for the field team every day.

### Heat Stress Monitoring Techniques

Site personnel should regularly monitor their heart rate as an indicator of heat strain by the following method:

Radial pulse rates should be checked by using fore and middle fingers and applying light pressure to the pulse in the wrist for one minute at the beginning of each rest cycle. If the pulse rate exceeds 110 beats/minute, the next work cycle will be shortened by one-third and the rest period will be kept the same. If, after the next rest period, the pulse rate still exceeds 110 beats/minute, the work cycle will be shortened again by one-third.

### **6.13 Slips, Trips and Fall Hazards**

On any work area, it is expected that the ground might be uneven. The ground surface might be unreliable due to settling. Surface debris might be present and wet or swampy areas can exist.

Employees will walk around, not over or on top of debris or trash piles. When carrying equipment, identify a path that is clear of any obstructions. It might be necessary to remove obstacles to create a smooth, unobstructed access point to the work areas onsite. Fallen trees with broken branches extending up into the air may be like a lance into or through a body should a person fall on one. Care must be taken to be observant and walk around these hazards. Be alert for plants with stickers and thorns that could pose a problem if improper footwear, clothing, and eye protection are not addressed.

## **7.0 Air Monitoring**

The need for air sampling is not anticipated by AECOM during the activities covered by this HASP. The AECOM PM, or the AECOM OSR, can prescribe personal air sampling based on observations or concerns recognized during the project.

## **8.0 Optional Personal Protective Equipment**

Personal protective equipment (PPE) may be worn during these activities to prevent on-site personnel from being injured by the safety hazards posed by the site and/or the activities being performed. The following table describes the PPE to be worn for general site activities and for certain specific tasks. Specialized items will be paid for by AECOM or by the employee/contract worker and reimbursed by the company.

## 8.1 Optional Personal Protective Equipment

Prior to the field activity, the SSO will discuss any personal protective equipment (PPE) requirements.

PPE Item	See Footnote
Hard Hat	1
Traffic Vests	1
Safety Glasses with Sideshields	2
Tyvek Coveralls	3
Nitrile Gloves	3
Cotton or Leather Work Gloves	As Needed
Ivy Block® or Ivy Screen® barrier cream	4
Snake Protection	5
Sun Protection Factor Sunscreen	6

### Footnotes

1. Traffic vests and hardhats are required when working within 20 feet of any public road or any private road with active traffic. SSO will determine when long sleeve shirts are required during field activity.
2. Safety glasses with sideshields are recommended to be worn when traveling through wooded areas.
3. Tyvek coveralls or equivalent and Nitrile gloves or equivalent may be worn to protect workers from poison ivy and poison oak when contact cannot be avoided.
4. Ivy Block® or Ivy Screen® barrier cream should be worn on exposed skin where there is a potential for exposure to poison ivy or oak.
5. Snake protection (e.g., boots and snake chaps) may be worn when walking through vegetated areas where there is a potential for this matter.
6. Sun protection factor (SPF): A number on a scale for rating sunscreens. SPF numbers on a package can range from as low as 2 to as high as 60. These numbers refer to the product's ability to screen or block out the sun's burning rays. Sunscreens with an SPF of 15 or higher are generally thought to provide useful protection from the sun's harmful rays.

## 8.2 Other Safety Equipment

The following additional safety items will be available at the site:

- Portable, hand-held eyewash bottles
- First-aid kit and germicidal cleaner wipes and/or soap, potable water and clean dressings
- Type A-B-C fire extinguisher
- Portable phones and/or hand-held transceivers, especially if cell tower signals are weak or non-existent
- If dusts become irritating, respirators should be donned. See respirator examples on website <http://store.pksafety.net/dustmasks.html>. The "100" is 99.97% effective, and is the current means of referring to a "HEPA" filter. To ensure that these **disposable dust masks** are providing the protection advertised, [Respirator Fit Testing](#) is recommended. A less than optimum fit will allow unfiltered air to bypass the filter media and take the path of least resistance. In general, all of these masks should be discarded after they become soiled, or breathing becomes difficult due to filter loading.

## 9.0 Site Control

### 9.1 Parking and Staging Areas

Parking will be restricted to areas that have been cleared of tall grass and combustible material. Vehicles parked on the public streets will be marked with cones both in front of and behind the vehicle.

### 9.2 General Site and Safety Practices

The following measures are designed to augment the specific health and safety guidelines provided in this plan.

- Take all trash out and dispose of properly. Do not litter.
- Smoking is permitted in all work areas. However, grass or forest fires are possible especially during drought conditions. Therefore, extinguish matches and cigarettes, preferably on the shoe sole and not the ground, and carry these items out to dispose of in a trash container to keep private property free of litter.
- It is recommended that hands and face be thoroughly washed upon leaving the work area and before eating, drinking, or any other activities.
- The use of alcohol or illicit drugs is prohibited during the conduct of field operations.
- Sunscreen lotion, spray, or foam of SPF 30 or higher for skin protection from the sun.
- Insect repellent for skin protection from insects.
- Pepper spray for angry feral hogs or dogs.
- Allergic reaction medication: Let SSO know if you have medicine for an allergic reaction that you self-administer, e.g., EpiPen. Benadryl will be provided in the medicine kit for mild allergic reactions.
- For field activity in moist or wet ground areas, the SSO may recommend rubber boots by staff.



## 10.0 Decontamination/Sanitation

### 10.1 Personal Decontamination/Sanitation

Germicidal cleaner wipes and/or a container of potable water and liquid soap will be made available so employees can wash their hands and face before eating or leaving the project area for the day. Fieldwork may result in picking up viruses, tuberculosis, bacteria, pseudomonad and other microscopic organisms. For germicidal cleaner wipes or soap washing, allow sufficient contact time, e.g., 20 to 30 seconds, for adequate cleaning and disinfection. Two or more cleanings may be required if the area is particularly soiled.

## 11.0 Training Requirements

Each worker subject to this HASP shall have copies of documentation that the requirements for training are current. Copies of these documents shall be made available to AECOM or AECOM's client upon request.

## **11.1 Health and Safety Training**

### **11.1.1 Biohazards**

All personnel performing activities covered by this HASP must have completed the AECOM training on reducing exposures to biological hazards.

### **11.1.2 Pre-Entry Briefing**

Prior to the commencement of on-site activities, a pre-entry briefing will be conducted by the SSO, or their assistant, to review the specific requirements of this HASP. Attendance of the pre-entry meeting is mandatory for all personnel covered by this HASP and must be documented on the attendance form provided in *Appendix C*. HASP Acceptance Forms should also be collected at the time of the Pre-Entry Briefing. All documentation should be maintained in the project file.

The Pre-Entry Briefing Form must be completed for each new employee before they begin work at the site. Short safety refresher meetings will be conducted, as needed, throughout the duration of the project.

## **12.0 Emergency Responses**

OSHA defines emergency response as any "response effort by employees from outside the immediate release area or by other designated responders (i.e., mutual-aid groups, local fire departments, etc.) to an occurrence which results, or is likely to result in an uncontrolled release of a hazardous substance." According to AECOM policy, AECOM personnel will not participate in any emergency response where there are potential safety or health hazards (i.e., fire, explosion, or chemical exposure). AECOM response actions will be limited to evacuation and medical/first aid as described within this section below. As such, this section is written to comply with the requirements of 29 CFR 1910.38 (a).

The basic elements of an emergency evacuation plan include:

- Employee training,
- Alarm systems,
- Escape routes,
- Escape procedures,
- Critical operations or equipment,
- Rescue and medical duty assignments,
- Designation of responsible parties,
- Emergency reporting procedures, and
- Methods to account for all employees after evacuation.

### **12.1 Employee Training**

Employees must be instructed in the site-specific aspects of emergency evacuation. On-site refresher or update training is required anytime escape routes or procedures are modified or personnel assignments are changed.

## **12.2 Alarm System/Emergency Signals**

An emergency communication system must be in effect at all sites. The simplest and most effective emergency communication system in many situations will be direct verbal communications. Each site must be assessed at the time of initial site activity and periodically as the work progresses. Verbal communications must be supplemented anytime voices cannot be clearly perceived above ambient noise levels (i.e., noise from heavy equipment; drilling rigs, backhoes, etc.) and anytime a clear line-of-sight cannot be easily maintained among all AECOM personnel because of distance, terrain, or other obstructions.

Verbal communications will be adequate to warn employees of hazards associated with the immediate work area. The property is occupied but AECOM may not have access to facility phones. Therefore, AECOM will bring a portable phone and/or hand-held transceivers to the site to ensure that communications with local emergency responders is maintained, when necessary.

## **12.3 Escape Routes and Procedures**

The SSO is responsible for providing escape route(s) from the site and an emergency muster point will be determined and identified to all workers during the project mobilization by the SSO.

Prior to mobilizing to a new project area, the SSO or his designee will confirm that the escape routes are clear and lead to a safe area.

## **12.4 Employee Accounting Method**

The SSO is responsible for identifying all AECOM personnel onsite at all times. AECOM and its subcontract employees will notify the SSO when they enter and leave the site. The SSO will account for all AECOM and its subcontract employees following an evacuation.

## **12.5 Injuries and Illnesses**

The phone numbers of the police and fire departments, ambulance service, local hospital, and AECOM representatives are provided in the emergency reference sheet on pages 1 to 5. This sheet will be posted in the site vehicle.

### **12.5.1 First Aid**

Minor injuries will be treated onsite using materials from the first-aid kit or other local sources. All cuts and abrasions will be cleaned with germicidal cleaner wipes and/or potable water and a clean dressing applied. The injured employee will be evaluated at the end of the work day and the following day when the employee arrives at the project site to determine whether the wound has started the healing process. The wound will be protected from contamination during the project activities.

### **12.5.2 Professional Treatment**

In the event an injury or illness requires more than first aid treatment, the SSO will accompany the injured person to the medical facility and will remain with the person until release or admittance is determined. The escort will relay all appropriate medical information to the on-site PM, OSR, and the RSM per directions provided in *Appendices E, F, and G*.

If the injured employee can be moved from the accident area, he or she will be brought to a safe area where their PPE will be removed. If the person is suffering from a back or neck injury the person will not be moved and the requirements for decontamination, if required, do not apply. The SSO must familiarize the responding emergency personnel about the nature of the site and the injury. If the responder feels that the PPE can be cut away from the injured person's body, this will be done on-site. If this not feasible, decontamination, if required, will be performed after the injured person has been stabilized.

## **12.6 Designation of responsible parties**

The SSO is responsible for initiating emergency response. In the event the SSO cannot fulfill this duty, the alternate SSO will take charge.

## **12.7 Emergency Response Drills**


A table-top run through of the evacuations procedures from the project site will be conducted the first day on the site and reviewed with all workers arriving on site after that date.

## **12.8 Incident Reporting and Investigation**

Any incident (other than minor first aid treatment) resulting in injury, illness or property damage requires an incident investigation and report. The investigation is to be conducted as soon as emergency conditions are under control. The purpose of the investigation is not to attribute blame but to determine the pertinent facts so that repeat or similar occurrences can be avoided. The responsible AECOM supervisor will prepare the "Supervisor's Report of Incident" in *Appendix F* and the Responsible Lead Investigator (RLI) will prepare the "Incident Investigation and Review" presented in *Appendix G* of this HASP. The injured AECOM employee's supervisor, the AECOM PM, OSR, and the RSM should be notified immediately of the injury.

If a subcontractor employee is injured, they are required to notify the AECOM SSO. Once the incident is under control, the subcontractor will submit a copy of their company's Incident investigation report to the AECOM SSO.

## **Appendix A - Stop Work Authority**

  <b>Stop Work Authority</b>  <b>AECOM Safety, Health and Environmental Procedure</b>	SH&E No.:	101
	Rev:	Original
	Date:	January 5, 2009

## 1.0 PURPOSE

To establish the minimum requirements for AECOM personnel to stop work if they believe there is an imminent Safety, Health, or Environmental risk as described below that will affect them, their co-workers, the public, or the environment.

## 2.0 SCOPE

This procedure applies to all US-based locations and projects.

## 3.0 DEFINITIONS

- **Discrepancy/Deficiency:** An omission or commission, a condition, or a situation that is in conflict with the procedures, standards, and the requirements of Safety, Health & Environmental (SH&E) standards.
- **Imminent Danger:** An impending or threatening situation, which, if left uncorrected, is likely to result in serious injury, property damage or environmental impairment.
- **Potentially Dangerous:** Minor violations that present a low potential for serious injury, property damage or environmental impairment.
- **Stop Work Order:** A directive to cease work issued for failure to follow procedures, imminent danger situations/conditions, accumulation of safety violations, etc. The Stop Work Order will apply to AECOM and its direct subcontractors placed at risk by the situations or conditions.

## 4.0 ROLES AND RESPONSIBILITIES

### 4.1 EMPLOYEES

- Any time an employee identifies a discrepancy, deficiency, or potentially dangerous condition or act that is likely to cause an unsafe or unhealthy situation or an imminent danger situation, it is his/her responsibility to stop work and bring it to the attention of the appropriate Office Manager, Site Safety Officer, Project Manager and/or Contractor representative.
- Any employee may report unsafe working conditions anonymously. Anonymous reporting must be done with sufficient detail and promptness to allow Management and the SH&E staff to initiate corrective action.

### 4.2 SITE SAFETY OFFICER OR LOCAL SH&E REPRESENTATIVE

- Initiate the development and implementation of corrective actions to eliminate the condition causing the Stop Work Order.
- Report the details of the Stop Work Order and any corrective actions implemented to the Project Manager and the appropriate Regional SH&E Manager.

### 4.3 PROJECT MANAGERS OR OFFICE MANAGERS

- Verify that corrective actions taken appropriately address the conditions leading to the Stop Work Order.
- Initiate additional corrective actions necessary to correct the conditions leading to the Stop Work Order.

- Communicate corrective actions and impacts on the project/office to the client and/or Region Management.
- Assure that documentation related to the Stop Work Order and corrective actions are placed in the project/office file.

#### 4.4 REGIONAL OPERATIONS MANAGERS AND DISTRICT MANAGERS

- Provide support to the implementation of corrective actions and communications with clients.
- Assure that there is no reprimand or reprisal associated with the initiation of a Stop Work Order.

#### 4.5 REGIONAL SH&E MANAGERS

- Provide technical guidance for the development and implementation of corrective actions.
- Communicate with the SH&E group and assist with the development of Shared Learning and Safety Alert notices.

### 5.0 PROCEDURE

It is AECOM's policy and firm commitment that employees are expected to stop work to prevent unacceptable exposure to work place hazards, including unsafe conditions or worker behaviors, without fear of reprimand or reprisal from their manager(s) or co-worker(s). Cases involving reprisal, reprimand, or any attempt to discourage the initiation of Stop Work Orders and reporting of unsafe or unhealthy conditions or situations within AECOM should be immediately reported to the employee's Office Manager, Human Resources Representative, and Regional SH&E Manager.

#### 5.1 AUTHORITY

AECOM's stop-work authority applies to all work locations controlled by AECOM, AECOM employees and AECOM-controlled subcontractor work activities. All AECOM personnel are authorized to stop work if there is an identified unsafe condition. If the responsible organization fails to provide resolution, or if at any time their acts, or failure to act, cause substantial harm or imminent danger to health and safety of project employees, the public or the environment, AECOM may issue an order stopping work in whole or in part. In the event that AECOM issues a Stop Work Order, an order issued by AECOM authorizing the resumption of work must be in place prior to restarting work.

- In most cases, a Stop Work Order affects only those areas immediately involved in the hazardous situation. AECOM may issue a Stop Work Order for a portion of the work area(s) or an entire work area when unacceptable risks exist that cannot be mitigated by reasonable engineering controls, administrative actions or personal protective equipment. The Stop Work Order will remain in effect until the responsible organization resolves the problem(s) and brings the work area(s) to satisfactory conformance with established SH&E requirements. Work will not resume until appropriate corrective actions have been completed, ensuring that the condition has been rectified. The Stop Work Order will apply to AECOM and its direct subcontractors placed at risk by the situations or conditions.

#### 5.2 SEVERITY OF HAZARDS

##### 5.2.1 Imminent Danger Situations

- Any employee may stop activities imminently dangerous to workers or the public.
- "Stopping work" includes stabilizing an imminent danger situation to the extent that it can be left unattended for a prolonged period of time until the issue is resolved.
- The person requesting the work stoppage will notify the organization responsible for the work.
- The responsible organization will notify AECOM project/office management immediately of any "stop work" action(s) taken to rectify the situation.
- Failure to comply with any Stop Work Order by an AECOM employee, in whole or in part, may result in disciplinary action. Failure to comply with any Stop Work Order by a subcontractor employee may result in the immediate removal from the project and/or office location.

## 5.2.2 Potentially Dangerous Situations

Informal stop work interventions to correct minor conditions (e.g., to remind workers to put on their hard hats, safety glasses, etc.) do not require formal notification.

If the minor condition cannot be corrected a formal Stop Work Order will be issued and work will not be resumed until the situation has been eliminated.

## 5.3 MANAGEMENT - ISSUED STOP WORK ORDERS

Region, District, and Office Managers, Project Managers and/or SH&E Managers may issue a formal Stop Work Order in the following situations:

- Imminent danger exists involving the public or employee's safety and health or damage to the environment, facilities, or property.
- Continuing work or equipment usage will result in significant repair, rework, or removal.
- A project, or any segment of the project, is executed improperly or is out of compliance with applicable regulations or standards.

## 5.4 RESUMING WORK

Work associated with the affected area or operation will not resume unless all corrective actions identified in the applicable Stop Work Order or have been completed and closed.

In accordance with SH&E 307, *Project Safety Meetings*, all personnel affected by the Stop Work Order will be instructed on the corrective actions and preventative measures taken.

## 5.5 RECORDS

The completed stop work order and any corrective action reports generated will be maintained at the project site for the duration of the project and placed in the closed project file.

## 6.0 REFERENCE MATERIAL

- SH&E 105 - Inspections, Audits, and Corrective Actions
- SH&E 307 - Project Safety Meetings

## 7.0 ATTACHMENTS

- Attachment 1 – Stop Work Order

## 8.0 REVISION HISTORY

Revision	Date	Change
Original	January 5, 2009	N/A
Revision 1		

**This Form must be completed if any of the Following Criteria are met per SH&E 101 – Stop Work Order:**

1. Imminent danger exists involving the public or employees' safety and health, the environment, facilities, or property.
2. Continuing work or equipment usage will result in significant repair, rework, or removal.
3. A project, or any segment of the project, is executed improperly or is out of compliance.

Project Information		
Project Name: Luce Bayou Interbasin Transfer	Project No. 60097600	Date
Project Manager: Jeff Eversberg, PE		Time
Reported By:		
Stop Work Order is the result of the following:		
<input type="checkbox"/> Inspection/Audit:	<input type="checkbox"/> Environmental Impairment	<input type="checkbox"/> Injury/Incident:
<input type="checkbox"/> Unsafe Condition(s)	<input type="checkbox"/> Unsafe Behavior	<input type="checkbox"/> Improper Scope of Work
<input type="checkbox"/> Other Safety Concern/Issue:		
Summary of Stop Work Order ( Describe)		

### Return to Work

The above Stop Work Order issues/concerns have been corrected and documented. By signing below, I certify that the above Stop Work Order scenario has been corrected and work is safe to resume.

Title:	Print Name:	Signature:
Project Manager:		
Party Issuing Stop Work Order:		
Sub-Contractor Supervisor: (If Applicable)		

**\*\*\* All Stop Work Orders will be sent to the SH&E Department for review\*\*\***

## **Appendix B - Health and Safety Plan Acceptance Form**

# **Health and Safety Plan Acceptance Form**

## **Luce Bayou Interbasin Transfer**

### **Southeast Texas**

I have reviewed a copy of the Health and Safety Plan prepared for the above-referenced site and activities.

I have read and understood its contents and I agree that I will abide by its requirements.

Name (Printed): \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

Representing: \_\_\_\_\_

## **Appendix C - Pre-Entry Briefing Attendance Form**

## Health and Safety Pre-Entry Briefing Attendance Form

## Luce Bayou Interbasin Transfer

## Southeast Texas

Conducted by:		Date Performed:	
Topics Discussed:	1.		
	2.		
	3.		
	4.		




Note: Review of the content of the HASP (Required)

[illegible]

## **Appendix D - Job Safety Analysis**

# Job Safety Analysis



JSA Type: <input type="checkbox"/> Investigation <input type="checkbox"/> O&M <input type="checkbox"/> Office <input type="checkbox"/> Construction <input type="checkbox"/> Other			<input type="checkbox"/> New <input type="checkbox"/> Revised	Date:																																
Work Activity:																																				
Personal Protective Equipment (PPE):																																				
Development Team	Position/Title	Reviewed By	Position/Title	Date																																
<table border="1"> <thead> <tr> <th>❶ Job Steps<sup>1</sup></th> <th>❷ Potential Hazards<sup>2</sup></th> <th>❸ Critical Actions<sup>3</sup></th> <th> Stop Work Criteria</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td>•</td> <td>•</td> </tr> <tr> <td></td> <td></td> <td>•</td> <td>•</td> </tr> <tr> <td></td> <td></td> <td>•</td> <td>•</td> </tr> <tr> <td></td> <td></td> <td>•</td> <td>•</td> </tr> <tr> <td></td> <td></td> <td>•</td> <td>•</td> </tr> <tr> <td></td> <td></td> <td>•</td> <td>•</td> </tr> <tr> <td></td> <td></td> <td>•</td> <td>•</td> </tr> </tbody> </table>					❶ Job Steps <sup>1</sup>	❷ Potential Hazards <sup>2</sup>	❸ Critical Actions <sup>3</sup>	 Stop Work Criteria			•	•			•	•			•	•			•	•			•	•			•	•			•	•
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1 – Target number of job steps: six to ten

## 2 – Codes for Potential Hazards:

Caught Between (CBT)	Contacted By (CB)	Caught On (CO)	Fall To Below (FB)	Overexertion (O)	Struck Against (SA)
Caught In (CI)	Contact With (CW)	Exposure (E)	Fall - Same Level (FS)	Release To (R)	Struck By (SB)

3 – Types of Critical Actions: Elimination, Engineering Controls, Safe Work Practice / SOP, Administrative Controls, and/or PPE.

4 – Stop Work Trigger: Condition or situation that would require work to be stopped and hazards re-assessed.

## **Appendix E - Incident Reporting Reference Card**

## **Incident Reporting Reference Card**

**Report all incidents to the Incident Reporting Hotline Number. 1 (800) 348-5046**

**Contact your supervisor (manager) and the Southwest & Mtn. Regional Safety Manager immediately after placing the call to the Incident Reporting Hotline.**



**RC Skaggs, SW & Mtn Regional Safety Mgr**

**Work: 1 (602) 337-2607**

**Cell: 1 (312) 912-2438**


1. **Call 911** if immediate medical attention is required
2. **Immediately report all** accidents, injuries, illnesses, and near-miss incidents to your supervisor
3. **Supervisor call SH&E Reporting Hotline 1-800-348-5046** by end of shift
4. **Supervisor call Regional Safety Manager (RSM) RC Skaggs office (602)337-2607 or cell (312) 912-2438 by end of shift.**
5. **Supervisor must fill out SRI** and all applicable parts (Sections 1 through 4 for all incidents, Sections 5 for motor vehicles incidents, Section 6 for property damage) and submit to OSR within 24 hours. Submit by fax (602) 337-2626 or e-mail [ralph.skaggs@aecom.com](mailto:ralph.skaggs@aecom.com)

**DO NOT contact WorkCare directly** for non-life threatening illnesses or injuries that may require medical intervention beyond first-aid, contact your manager for instructions.

**Southwest & Mountain Regional Safety Manager:**

**Mr. RC Skaggs D (602) 337-2607; C (312) 912-2438**

## **Appendix F - Incident Reporting**

 Incident Reporting <b>AECOM Safety, Health and Environmental Procedure</b>	SH&E No.:	201
	Rev:	Original
	Date:	January 5, 2009

## 1.0 PURPOSE

To ensure that all Safety, Health & Environmental (SH&E) incidents are documented and reported in a timely and accurate manner. Additionally, ensure that appropriate lessons-learned are gathered from all SH&E incidents and that all information required for regulatory reports is generated and filed as required for compliance.

## 2.0 SCOPE

This procedure applies to all US-based locations and projects.

## 3.0 DEFINITIONS

**SRI** – Supervisor’s Report of Incident (see *Attachment 2*)

**SH&E Incidents** - The following events or situations as applied to AECOM employees and/or AECOM-controlled operations are considered SH&E Incidents:

1. Any work-related injury or illness to an AECOM or subcontractor employee (hereafter in this SOP subcontractor refers to AECOM-controlled).
2. Fire, explosion, or flash that is not an intended result of a remediation process, laboratory procedure, or other planned event.
3. Any accidents involving company-owned, rented, or leased vehicles (including personal vehicles used for company business).
4. Any breach of a numeric limit attached to a governmental permit or consent.
5. Any failure to perform the requirements of a non-numeric requirement contained in a government permit or consent.
6. Any failure to obtain a government permit or consent when required (including failure to obtain revisions before an existing permit or consent expires).
7. Any notice of violation or notice of non-compliance received from a regulatory authority with enforcement powers.
8. Property damage resulting from any AECOM or subcontractor activity.
9. Unexpected release or imminent release of a hazardous material.
10. Unexpected chemical exposures to workers or the public.
11. A safety, health, or environmental related complaint from the public regarding AECOM activities.
12. SH&E-related incidents that could result in adverse public media interest concerning AECOM or an AECOM project.
13. Any inspection by a federal, state, or local safety, health, & environmental enforcement agency.
14. Near-Miss Incidents, defined as an incident having the potential to cause injury, health effects, environmental impairment, or property damage as described in the above categories – but did not. *Attachment 3* is used to report near-miss incidents.

15. Significant Learning Experience, defined as a near-miss incident that the affected group (i.e. project team, office staff, etc.) believes could have wide-ranging impacts throughout AECOM.

**Fatality** – Loss of life of any AECOM employee, AECOM subcontractor personnel, client personnel or member of the general public that can be perceived to be related to work performed or controlled by AECOM.

**Serious SH&E Incident** – Any SH&E Incident that meets/involves the following criteria

- Any amputation
- Any loss of conscious
- Hospitalization for treatment (admission)
- Absence from work for more than 30 calendar days due to work-related injury/illness
- Fracture of a bone
- Any single event resulting in more than one employee requiring medical treatment
- Any SH&E-related Consent Agreement/Order/Lawsuit or enforcement action seeking more than \$10,000 or alleging criminal activity
- Any spill or release of a hazardous material that is reportable to a government agency
- Any Notice of Violation resulting from failure to operate within the requirements of a government permit or consent
- Near-miss incidents that, in the opinion of the Business Line Manager, Regional SH&E Manager, Regional Chief Executive, Group or Corporate SH&E Director, may have otherwise resulted in any of the above

## 4.0 ROLES AND RESPONSIBILITIES

### 4.1 EMPLOYEES

- Each employee involved in an SH&E incident must notify his/her supervisor immediately (see 5.1 and 5.2 for specific timing) that an incident (including a near-miss) has occurred, the circumstances involved, the nature and extent of the injuries/illness, and whether medical treatment may be required. Except for emergency situations, affected employees are required to discuss their injury/illness status with their supervisor and Regional SH&E Manager or project SH&E Professional prior to obtaining medical treatment.
- Assist supervisor in completing appropriate reporting and investigation forms.

### 4.2 SUPERVISORS

- In an emergency/life-threatening situation, supervisors use the appropriate local emergency phone numbers and seek immediate medical care for the employee.
- Follow the directions provided by the AECOM SH&E Incident Reporting Hotline (800-348-5046) by the end of the current work shift.
- Contact the Regional SH&E Manager if immediate procedural assistance is required.
- Complete the applicable sections of the incident reporting forms (e.g., Supervisor's Report of Incident [SRI] or Near-Miss Reporting Form) and fax a draft (or preliminary) copy to AECOM Corporate SH&E Department at (562-499-4012) within 24 hours of the incident.
- Notify the appropriate line or lead manager (i.e., manager responsible for personnel involved/project oversight/business line, etc.).
- As appropriate, initiate an Incident Investigation and Review per the requirements of SH&E SOP 204.
- Fatalities and/or serious SH&E incidents must be reported to the appropriate Regional SH&E Manager and/or Group SH&E Director as soon as reasonably possible but no more than **2 hours** after the incident.

## 5.0 PROCEDURE

### 5.1 FATALITY OR SERIOUS SH&E INCIDENT NOTIFICATION

Any fatality or serious SH&E incident is to be directly reported as soon as practical (i.e. as soon as the site is secure and appropriate local emergency response is coordinated), but in no case more than 2 hours after the incident, to the appropriate Group Chief Executive, Regional Chief Executive, Regional SH&E Manager and Group SH&E Director. Voicemail and/or email alone are not adequate to meet this requirement. The responsibility for this reporting belongs to the responsible line manager (i.e. office/project manager).

Notification to external regulatory agencies (i.e. OSHA) is to be done in accordance with SHE SOP 205.

### 5.2 MEDICAL TREATMENT INJURY, HAZARDOUS MATERIAL SPILL/RELEASE, PERMIT CONDITION NOTIFICATION

Any SH&E incident involving medical treatment for an AECOM employee, release of a hazardous material and/or breach of a numeric or non-numeric permit/consent limit is to be reported as soon as possible, but not later than the end of the work-shift, to the Regional SH&E Manager, Regional/Business Line Manager and Group SH&E Director either verbally or via email. Responsibility for this reporting belongs to the responsible project/location/department manager.

### 5.3 INTERNAL SH&E INCIDENT REPORTING

The "Supervisor's Incident Reporting Flowchart" (*Attachment 1*) provides specific guidance on the steps necessary to report and document SH&E incidents.

## 6.0 REFERENCE MATERIAL

- SH&E 204 – Incident Investigation
- SH&E 205 – OSHA Recordkeeping and Reporting

## 7.0 ATTACHMENTS

Attachment 1 - Supervisor's Incident Reporting Flowchart

Attachment 2 - Supervisor's Report of Incident

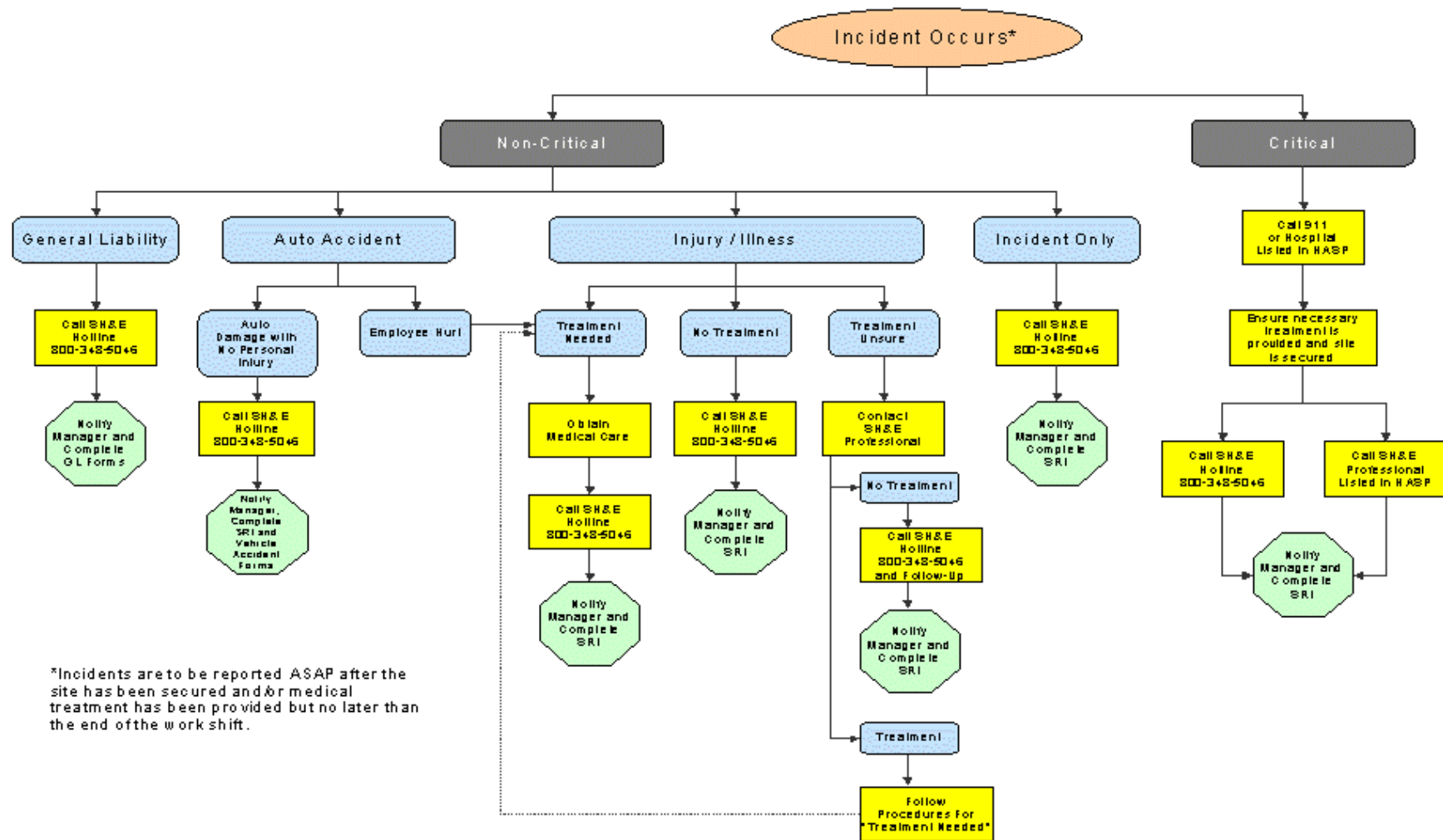
Attachment 3 - Near-Miss Incident Report

## 8.0 REVISION HISTORY

Revision	Date	Change
Original	January 5, 2009	N/A
Revision 1		

•

## Supervisor's Incident Reporting Flowchart



## Supervisor's Report of Incident

1. Seek immediate medical attention if necessary.
2. Employee must report **all** incidents to their supervisor **immediately**.
3. Supervisor calls the Incident, Injury and Near Miss Reporting Line at **(800) 348-5046**.

### Section 1 - Organization Information

Region: <input type="checkbox"/> West <input type="checkbox"/> Midwest <input checked="" type="checkbox"/> Southwest/Mountain <input type="checkbox"/> Southeast <input type="checkbox"/> Mid-Atlantic <input type="checkbox"/> Northeast	Houston Water:	Section/Dept Number:
Business Line: <input checked="" type="checkbox"/> Infrastructure-Water <input type="checkbox"/> Infrastructure-Transportation <input type="checkbox"/> Infrastructure-Energy & Power <input type="checkbox"/> PDD-Facilities <input type="checkbox"/> PDD-Design <input type="checkbox"/> Environmental		Houston:
Client Name: <b>Coastal Water Authority</b>		Project Number: <b>60097600</b>
Project Name: <b>Luce Bayou Interbasin Transfer</b>		

### Section 2 - Type of Incident (SRI Sections to Be Completed)

<input type="checkbox"/> Injury/ illness (Sections 3, 4, and 7)	<input type="checkbox"/> Vehicle Incident (Sections 3, 4, 5, and 7)	<input type="checkbox"/> Property Damage (Sections 3, 4, 6 and 7)	<input type="checkbox"/> Environmental Spill/Release (Sections 3, 4, and 7)
<input type="checkbox"/> Regulatory Inspection or Notification: (Sections 3, 4, 7)			<input type="checkbox"/> Other (describe)

### Section 3 - Contact/Incident Information

Employee/Claimant Name:		Employee Job Title:	<input type="checkbox"/> Full-Time Employee <input type="checkbox"/> Subcontractor/Subconsultant <input type="checkbox"/> Temp Agency Employee <input type="checkbox"/> Part-Time Employee <input type="checkbox"/> Third Party Employee
Work Phone:	Cell Phone:	Home Phone:	Employee Number:

Date/Time of Incident:	Date/Time Reported to Supervisor:	
Street Address of Incident or approximately:	City:	State/Zip:
Body Part Injured:	Type of Treatment:    Medical/hospital or doctor <input type="checkbox"/> First Aid Only <input type="checkbox"/>	
Medical Facility Contact Info: (Name, Address, Phone)		

## Section 4 - Descriptions of Incident (employee, supervisor and witness statements)

<b>Employee Description of Incident:</b>	
(use additional paper if necessary)	
<b>Employee Signature:</b>	<b>Date and Time:</b>

**Supervisor Description of Incident:** (Supervisor signs in Section 7)

(use additional paper if necessary)

Witness Name :

Witness Address:

Witness Phone  
No.:

**Witness Description of the Incident:**

(use additional paper if necessary)

**Witness Signature:**

**Date and time:**

Section 5 - Vehicle Incident Information *(fill out for motor vehicle incidents only)*

5a - AECOM Driver Name:		Drivers License #:	State Issued:	Expiration Date:	
Vehicle Year:	Make:	Model:	Color:	License Plate:	State:
VIN Number:					
<b>AECOM Vehicle was:</b> <input type="checkbox"/> AECOM Owned <input type="checkbox"/> Rented <input type="checkbox"/> Leased <input type="checkbox"/> Personal Vehicle		<b>Who was involved?</b> <input type="checkbox"/> AECOM Vehicle(Section 5a) <input type="checkbox"/> Pedestrian <input type="checkbox"/> Another Vehicle(Section 5b) <input type="checkbox"/> Property			
Use of Vehicle at Time of Incident: <input type="checkbox"/> Office Visit <input type="checkbox"/> Site Visit <input type="checkbox"/> Client Meetings <input type="checkbox"/> Field Work <input type="checkbox"/> Personal <input type="checkbox"/> Other_____			Vehicle Type: <input type="checkbox"/> Commercial Motor Vehicle <input type="checkbox"/> Non Commercial Motor Vehicle		
5b - Name of Other Driver:		Address:	City:	State/Zip:	
Work Phone:		Cell Phone:			
Date of Birth:	Drivers License #:	State Issued:	Expiration Date:		
Vehicle Year:	Make:	Model:	Color:	License Plate:	State:
VIN Number, Insurance Company Name, Insurance Policy Number:					

<b>If Vehicle Owner is different from driver then complete owner's contact information</b>	<b>Owner Name:</b>	
	Address, City, State, Zip:	
	Work Phone:	Cell Phone:
Authorities contacted? <input type="checkbox"/> Yes <input type="checkbox"/> No	If so, who responded?	
Citations Issued? <input type="checkbox"/> Yes <input type="checkbox"/> No	Type of Citation:	Person Cited:

Section 6 - General Liability *(Fill out for property damage only)*

Description of damaged property:	
Where can the property be seen?	
Property Owner Name:	
Address, City, State, Zip:	
Work Phone:	Cell Phone:

## Section 7 - Signatures

**Supervisor**

Print Name:	Signature:	Date:	Telephone:
-------------	------------	-------	------------

**Office/Location Manager**

Print Name:	Signature:	Date:	Telephone:
-------------	------------	-------	------------

**Regional SH&E Manager**

Print Name:	Signature:	Date:	Telephone:
Comments:			

***Attention: This form must be completed and forwarded to the Regional SH&E Manager within one (1) business day following the occurrence of the incident.***

## NEAR MISS INCIDENT REPORT

Name of Involved Employee(s) \_\_\_\_\_ Date of Incident \_\_\_\_\_ Time \_\_\_\_\_ am/pm

Office Name \_\_\_\_\_ Date Reported \_\_\_\_\_ Time \_\_\_\_\_ am/pm

Project Name Luce Bayou Interbasin Transfer Project Number 60097600 State Texas

Manager \_\_\_\_\_ Supervisor \_\_\_\_\_

Describe what happened. Please be precise. \_\_\_\_\_

---

---

---

How could this incident have been avoided? \_\_\_\_\_

---

---

Recommended follow-up action(s):

---

---


---

---

Supervisor's signature \_\_\_\_\_ Date \_\_\_\_\_

*(If more room is needed, use other side)*

## **Appendix G - Incident Investigation and Review**

 Incident Investigation and Review <b>AECOM Safety, Health and Environmental Procedure</b>	SH&E No.:	204
	Rev:	Original
	Date:	January 5, 2009

## 1.0 PURPOSE

To ensure that all Safety, Health & Environmental (SH&E) incidents are investigated in a timely and thorough manner. Additionally, ensure that appropriate lessons learned are gathered from all SH&E incidents and that information is shared regarding lessons learned throughout the organization.

## 2.0 SCOPE

This procedure applies to all US-based locations and projects.

## 3.0 DEFINITIONS

**Responsible Lead Investigator (RLI)** – Operations Manager responsible for the incident investigation, as established by the Responsible Lead Investigator table in *Attachment 1*.

**SRI** – Supervisor's Report of Incident (see SH&E 201, *Attachment 2*).

**SH&E Incidents** – The following situations as applied to AECOM employees and/or AECOM controlled operations are considered SH&E Incidents:

1. Any work-related injury or illness to an AECOM or subcontractor employee.
2. Fire, explosion, or flash that is not an intended result of a remediation process, laboratory procedure, or other planned event.
3. Any accidents involving company-owned, rented, or leased vehicles (including personal vehicles used for company business).
4. Any breach of a numeric limit attached to a governmental permit or consent.
5. Any failure to perform the requirements of a non-numeric requirement contained in a government permit or consent.
6. Any failure to obtain a government permit or consent when required (including failure to obtain revisions before an existing permit or consent expires).
7. Any notice of violation or notice of non-compliance received from a regulatory authority with enforcement powers.
8. Property damage resulting from any AECOM or subcontractor activity.
9. Unexpected release or imminent release of a hazardous material.
10. Unexpected chemical exposures to workers or the public.
11. A safety, health or environmental related complaint from the public regarding AECOM activities.
12. SH&E-related incidents that could result in adverse public media interest concerning AECOM or an AECOM project.
13. Any incident that could result in, or any actual investigation by a Federal, State, or local safety, health or environmental enforcement agency.
14. Near-Miss Incidents, defined as an incident having the potential to cause injury, health effects, environmental impairment, or property damage as described in the above categories – but did not.

15. Significant Learning Experience, defined as a near-miss incident that the affected group (i.e. project team, office staff, etc.) believes could have wide-ranging impacts throughout AECOM.

**Fatality** – Loss of life of any AECOM employee, AECOM subcontractor personnel, client personnel or general public that can be perceived to be related to work performed or controlled by AECOM.

**Serious SH&E Incident** – Any SH&E Incident that meets/involves the following criteria:

- Any amputation.
- Any loss of conscious.
- Hospitalization for treatment (admission).
- Absence from work for more than 30 calendar days due to work-related injury/illness.
- Any single event resulting in more than one employee requiring medical treatment.
- Any SH&E-related Consent Agreement/Order/Lawsuit or enforcement action seeking more than \$10,000 or alleging criminal activity.
- Any spill or release of a hazardous material that is reportable to a government agency
- Any Notice of Violation resulting from failure to operate within the requirements of a government permit or consent.
- Near-miss incidents that, in the opinion of the Business Line Manager, Regional SH&E Manager, Regional Chief Executive or Group SH&E Director, may have otherwise resulted in any of the above.

## 4.0 ROLES AND RESPONSIBILITIES

### 4.1 EMPLOYEES

Each employee involved in an SH&E incident must:

- Notify his/her supervisor immediately that an incident (to include near misses) has occurred, the circumstances involved, the nature and extent of the injuries/illness, and whether medical treatment may be required.
- Assist supervisor in completing/conducting appropriate incident investigations.

### 4.2 SUPERVISORS

Supervisors are required to:

- Ensure all incidents are reported in accordance with SH&E 104 – Incident Reporting.
- Lead/Participate in formal Incident Investigation as required by this procedure.

### 4.3 MANAGEMENT

Managers are responsible to:

- Lead/Participate in the formal Incident Investigation process as required by this procedure.
- Schedule and conduct Incident Review calls as required by this procedure.

### 4.4 REGIONAL SH&E MANAGER

Regional SH&E Managers are required to:

- Provide training on incident investigation techniques and tools to selected investigation teams.

- Participate on investigation teams and Incident Review Calls when requested by the Responsible Lead Investigator.
- Maintain Incident Investigation Report files for the Region.
- Track and report on the status of all action items identified within final Incident Investigation Reports.
- Provide final Incident Investigation Report to the Corporate SH&E Administrator for inclusion in permanent incident files.

## 5.0 PROCEDURE

### 5.1 INITIAL POST- INCIDENT RESPONSE PROCEDURE BY OFFICE/PROJECT TEAM

Immediate steps to be taken by local field/office personnel:

- Provide First Aid for any injured persons.
- Eliminate or control identified hazards at the scene.

Other steps to be taken by local field/office personnel:

- Secure the area. Do not disturb the scene until relevant facts are obtained unless an immediate hazard exists.
- Prepare appropriate sketches and or obtain photographs of the incident scene and gather relevant information from the scene (Who, What, Where, When and other “environmental factors” that may have had an influence on the incident).
- Call the AECOM Incident Reporting Hotline at 1-800-348-5046.
- Interview witnesses and document responses as soon as possible at the scene of the incident.

### 5.2 FOLLOW – UP INVESTIGATION

#### 5.2.1 Identify Responsible Lead Investigator

- The Responsible Lead Investigator (RLI) Table (*Attachment 1*) will be used to identify the management representative responsible for conducting the appropriate incident investigation.
- The RLI will appoint an appropriate team to conduct and document the required investigation.

#### 5.2.2 Investigation Team Procedures

- The team will follow an appropriate investigation technique (as agreed to by the RLI and Regional SH&E Manager) to determine the following:
  1. Sequence of events leading up to the incident and steps followed immediately following the incident that may have had an impact on the final outcome.
  2. Identification of the People, Parts/Equipment, Position and Paper/Documentation factors involved in the incident.
  3. Determination of direct cause(s) and root causes using techniques agreed to by the RLI and SH&E Manager. (Note: Example root cause investigation tools include “5 Why’s,” TapRoot, Fishbone Diagram, etc.).
- The Investigation Team will prepare a preliminary report, signed by the RLI, documenting all findings and recommended corrective actions within 10 business days following the incident.
- The preliminary investigation report format for all incidents classified as category 3 or higher in *Attachment 1* will follow the template provided in *Attachment 2*. All other reports will be at the discretion of the responsible Regional SH&E Manager.

- Where required by the RLI Table, an investigation Review Call will be held to review the preliminary investigation report. Required participants for the call will include:
  - The direct supervisor of the Responsible Lead Investigator.
  - Responsible Supervisor or Project Manager of the injured/involved employee.

For example, if the Responsible Lead Investigator is a District Business Line Manager, the Regional Business Line Manager, responsible Office/Project Manager and direct Supervisor of the involved employee will be required participants. If the Responsible Lead Investigator is the Project Manager, the Location Manager and Field Supervisor would be required participants.

**Note:** Incident Review Calls are designed to summarize the preliminary investigation findings and come to agreement on contributing factors, root causes and appropriate corrective actions. Direct participation by the employee(s) involved in the incident is not necessary and requires prior approval from the Senior Manager assigned to the incident review committee. Other members of the incident review committee will be at the discretion of the most Senior Manager involved in the committee.

The RLI will extend an invitation to the Corporate and Group SH&E Directors at least 5 days prior to the scheduled review date. The Corporate SH&E Director will extend an invitation to other senior and executive management members based on a preliminary assessment of the incident:

- Final investigation reports (following incident review call where required) are to be forwarded to the responsible Group SH&E Director, Regional SH&E Manager and Corporate SH&E Administrator for inclusion in the permanent incident files.

### 5.2.3 Communication of Investigation Results

- Where appropriate based on the type, severity and/or scope of the incident, a formal Alert will be prepared by the RLI and responsible Regional SH&E Manager. The Alert will be communicated to the most appropriate audience (i.e. regional, national, business line only, etc.).
- Action items and corrective actions identified by the RLI and investigation teams will be tracked to completion by the responsible Regional SH&E Manager. Additionally, the results will be utilized by the SH&E department to develop appropriate regional, national and business line level reports and to improve existing procedures.

## 6.0 REFERENCE MATERIAL

- SH&E 104 – Incident Reporting

## 7.0 ATTACHMENTS

Attachment 1 - Responsible Lead Investigator Table

Attachment 2 - Incident Investigation Report Template

## 8.0 REVISION HISTORY

Revision	Date	Change
Original	January 5, 2009	N/A
Revision 1		

Attachment 1  
Responsible Lead Investigator Table

	Incident Classification	Project Super. or Employee Supv.	Project - Location Manager	District Business Line Mgr.	Regional Business Line Mgr.	Formal Report and Review Call Required
<ul style="list-style-type: none"> <li>Unsafe Condition/Action</li> <li>Near-Miss Incident</li> </ul>	1	X				
<ul style="list-style-type: none"> <li>Property Damage (less than \$5,000)</li> <li>First-Aid Only Case</li> <li>Any Environmental Release (less than Reportable Quantity)</li> </ul>	2	X				
<ul style="list-style-type: none"> <li>Significant Learning Experience</li> <li>Recordable Injury/Illness</li> <li>Property Damage over \$5,000</li> <li>Regulatory NOV. (i.e. OSHA Citation, EPA NOV, etc.)</li> </ul>	3		X			X
<ul style="list-style-type: none"> <li>Serious SH&amp;E Incident</li> <li>Property Damage over \$100,000</li> </ul>	4			X		X
<ul style="list-style-type: none"> <li>Fatality</li> </ul>	5				X	X

## Executive Summary

### Brief Summary:

*Provide a summary of the incident that includes all critical elements of the investigation*

### What went wrong?

*Provide a bulleted list of the most critical elements in the incident sequence that “failed” or were overlooked*

### What went well?

*Provide a list of the most important elements of the incident sequence, including post-incident elements that went well*

### Critical Factors and Root Causes:

#### Critical Factors

*Based on the interviews, site investigations, and other evidence gathered, identify the events, conditions, and/or actions (Critical Factors) that were directly responsible for the incident*

#### Root Causes

*Using an appropriate tool, identify the root causes of the incident*

### Action Items:

*Identify the action items from the investigation.*

### Lessons Learned:

*Provide any information that the investigation team believes will assist other operations, projects, offices, and/or employees avoid this type of incident.*

# REPORT

## I. General Background

*Provide basic contract information as well as pertinent site information*

## II. Incident Description

*Complete and detailed description of all aspects leading up to the incident, the incident itself, and any applicable post-incident measures that either lessened, controlled, and/or exacerbated the final outcome of the incident.*

## III. Incident Timeline

*Provide a chronological description of the events leading up to the incident and any actions following the incident that may have had an impact on the outcome*

## IV. Investigation Results

### A. People Factors

*Describe and evaluate all personnel involved including their roles, responsibilities, experience, and training*

### B. Parts/Equipment Factors

*Describe and evaluate (using pictures or drawings where necessary) all equipment and/or parts involved. Include information relative gauge levels, meter readings, physical condition, etc.*

### C. Position Factors

*Describe and evaluate the layout of the incident area noting the location of all people, equipment, structures, etc.*

### D. Paper/Documentation Factors

**Describe and evaluate compliance with the procedures, programs, plans, specifications, etc. applicable to the task being performed and the people performing the task. For example, Task Hazard Analysis, project safety plan, corporate and/or project procedures, training requirements, etc.**

V. Incident Analysis

For each Critical Factor identified during the investigation, identify each applicable root cause in the table below. Use a separate table for each Critical Factor.

Critical Factor 1

Identified Root Cause	Cause Type	Cause No.	Cause Description

Critical Factor 2

Identified Root Cause	Cause Type	Cause No.	Cause Description

## VI. Action Plan

*Based on the investigation and root cause analysis, the following actions have been planned.*

[illegible]

# THE ECOLOGY OF FRESHWATER MUSSELS: SPECIES OF INTEREST



**Robert G. Howells**

**BioStudies, 160 Bearskin Tr., Kerrville, Texas 78028**

**biostudies@hctc.net**

**Prepared for**

**Texas Comptroller's Freshwater Mussel Summit**

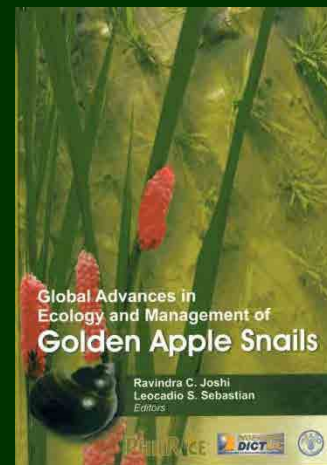
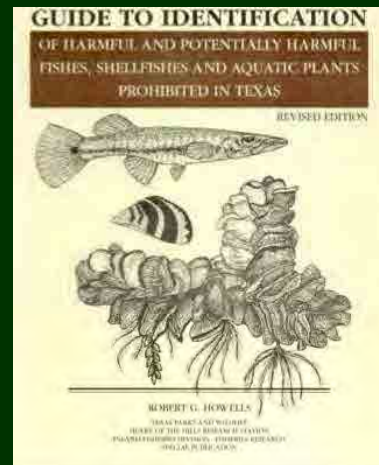
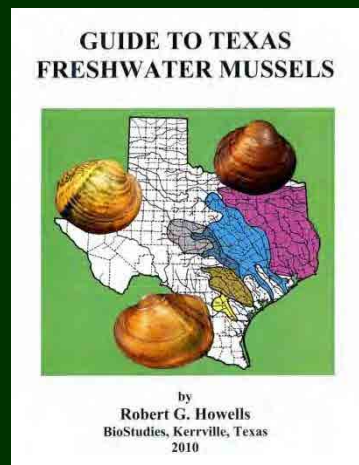
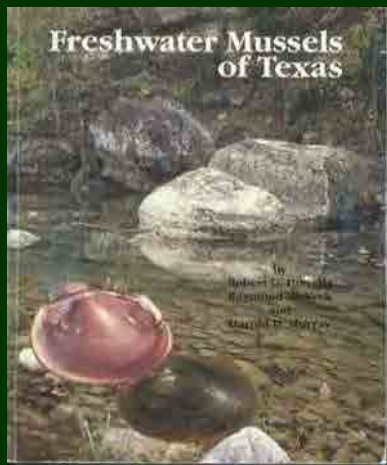
**Austin, Texas – 27 September 2010**

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# FOR THOSE WHO DON'T KNOW ME

- Fishery Scientist – Aquatic Ecologist
- Work History
  - Cleveland Museum of Natural History
  - Ichthyological Associates, Inc. (10 yrs) - Environmental Consulting Firm
  - Texas Parks and Wildlife Department (22 yrs)  
Heart of the Hills Fisheries Science Center
    - Basic fisheries research
    - Freshwater mussels
    - Exotic fishes, shellfishes, & aquatic plants
  - Retired June 2006
    - Continuing similar work, consulting, writing



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# TERMINOLOGY – WHAT IS A MUSSEL?

- **“MUSSEL” AND “CLAM” ARE NOT SPECIFIC TERMS**
- **Mussels – a common term for many families of freshwater and marine bivalves that may be unrelated**
- **Clam – a common term for many families of fresh water and marine bivalves that may be unrelated**
- **Unionids – refers to family Unionidae**
- **Pearly freshwater mussels –  
species of Unionidae & Margaritiferidae**
- **Naiad (naiade) refers to freshwater mussels of the family Unionidae (also Margaritiferidae) in the U.S.; also used for aquatic insect larvae**



# MEMBERS OF SEVERAL BIVALVE FAMILIES LIVE IN FRESH WATERS

- Freshwater mussels (Unionidae, Margaritiferidae)
- Fingernail clams (Sphaeriidae) – very small
- Asian clams (Corbiculidae) – introduced exotics, with one native representative
- Zebra mussels (Dreissenidae) – two introduced exotic & one native species
- Atlantic rangia (Mactridae) – estuarine & marine; may live in fresh water, but need salt to reproduce; often important in coastal archeology

**\*\* Other families exist in the southern hemisphere, including Mexico and southern Asia**



# FRESHWATER MUSSEL INTRODUCTION

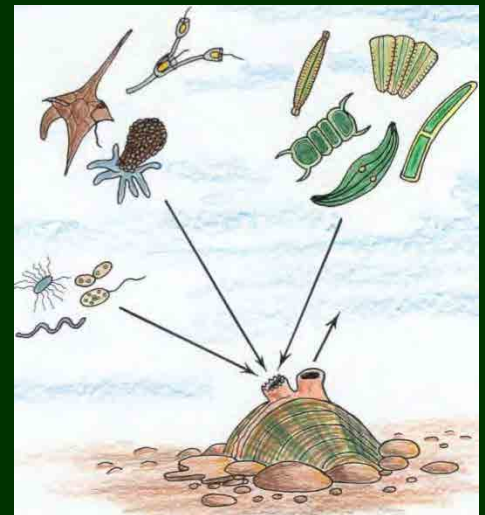
- FRESHWATER MUSSELS ARE IMPORTANT ELEMENTS OF AQUATIC ECOSYSTEMS.
- THEY ARE SENSITIVE BAROMETERS OF ENVIRONMENTAL QUALITY.
  - When ecological conditions decline or are altered, this is the first group to decline and vanish.
- THEY ARE THE FASTEST DECLINING FAUNAL GROUP IN THE U.S., INCLUDING TEXAS.
  - Perhaps 80% of U.S. species are now extinct, endangered, threatened, or will be very soon.
  - In Texas, about half of our species have declined to dangerously low numbers, including all our endemic species.

Texas species range in size from washboards that weigh 4 lbs and grow to nearly 12 inches long and Texas lilliputs that mature under an inch in length.



# BASIC MUSSEL BIOLOGY

- **Freshwater mussel juveniles and adults dig into the substrate. They do not attach to solid objects with byssal threads as do marine mussels and zebra mussels.**
- **Movement is usually limited to crawling short distances.**
- **Adults and older juveniles filter feed on plankton, bacteria, and organic material in the water column and possibly the substrate.**



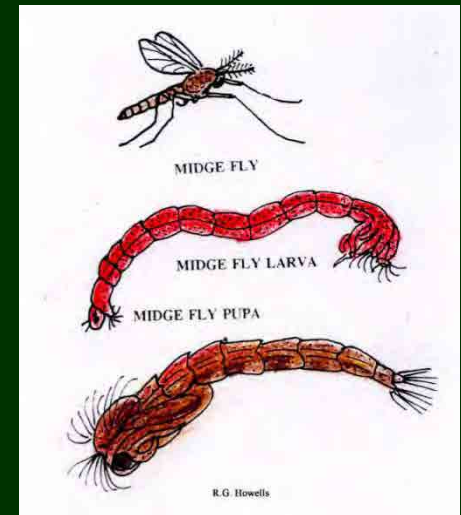
# GENERAL FRESHWATER MUSSEL HABITAT

- Unionids in Texas may occur in lakes, reservoirs, ponds, streams, & rivers with bottoms of mud, clay, stable sand, gravel, & mixtures of these (some are habitat specific).
- Often types of unacceptable habitats are more important aspects of distribution.
- Unacceptable habitat includes:
  - Deep shifting sand
  - Deep soft silt
  - Scoured cobble and bedrock
  - Severe long-term dewatering (drought or drawdown)
  - Dramatically fluctuating water levels
  - Dense aquatic plant beds or rafts
  - Substrates covered with leaves & sticks, etc.
- Unacceptable habitat – cont.
  - Low-quality polluted waters
  - Saline waters
  - Lack of host fishes
  - Headwater springs
  - Impounded waters (some species)



# ASSOCIATED SPECIES

- **FRESHWATER MUSSELS SUPPORT A VAST ARRAY OF COMMENSAL AND PARASITIC ORGANISMS INSIDE AND OUTSIDE THEIR SHELLS.**
  - Some midge larvae, mites, aquatic earthworms, and leaches occur only inside freshwater mussels.
  - When mussels are lost, whole micro-communities are also lost.



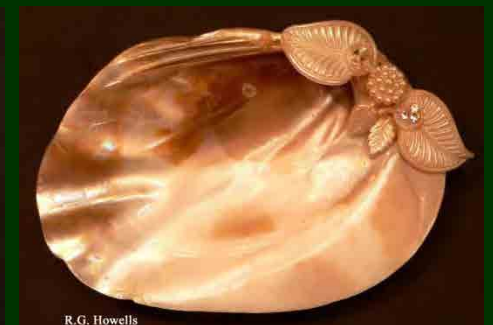
# IMPORTANCE IN THE AQUATIC ECOSYSTEM

- Freshwater mussels are important components of aquatic ecosystems.
- They are key indicator species that alert us to ecological problems.
- Mother-Nature's biofilters
  - They remove algae, bacteria, protozoans, particulate matter, and other material from the water.
  - Consider: Would the brain-eating amoeba, *Naegleria*, now present in the Colorado River be a significant risk to humans if mussels were filtering it from the water column?
- Concentrate and sequester pesticides, heavy metals, and other environmental contaminants.
- Food for numerous other organisms.
- Mix aquatic substrates as earthworms do in gardens.
- Legally-protected species can be a hedge against destructive development and habitat modification.



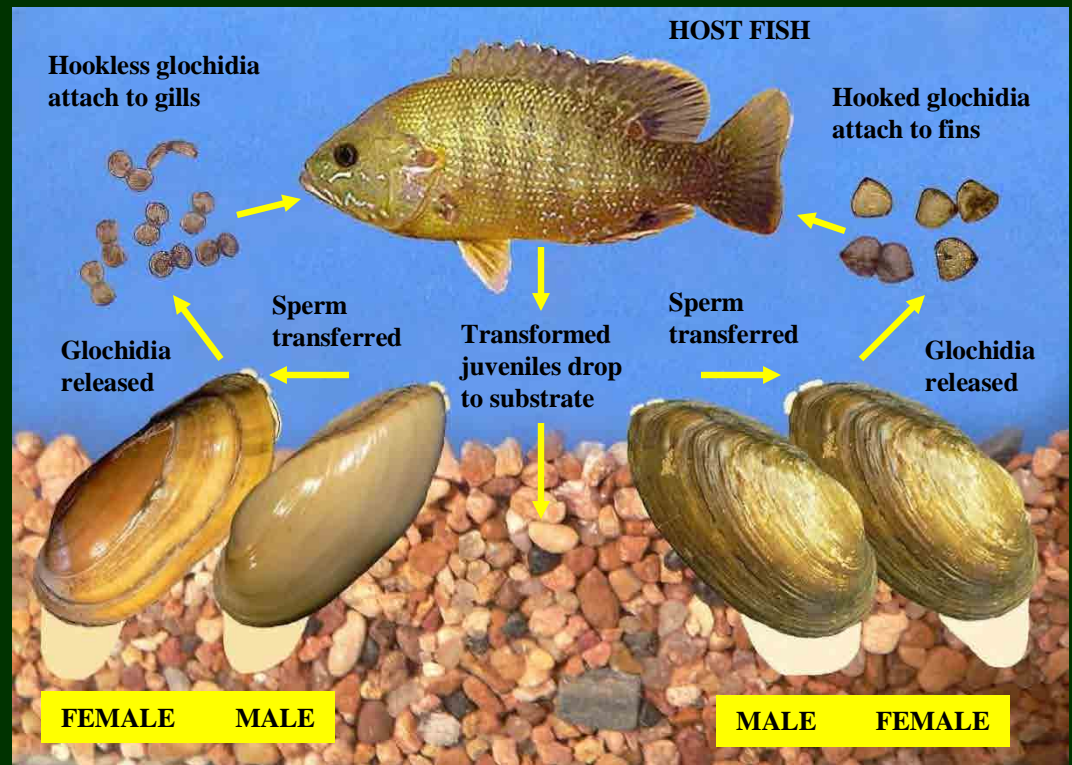
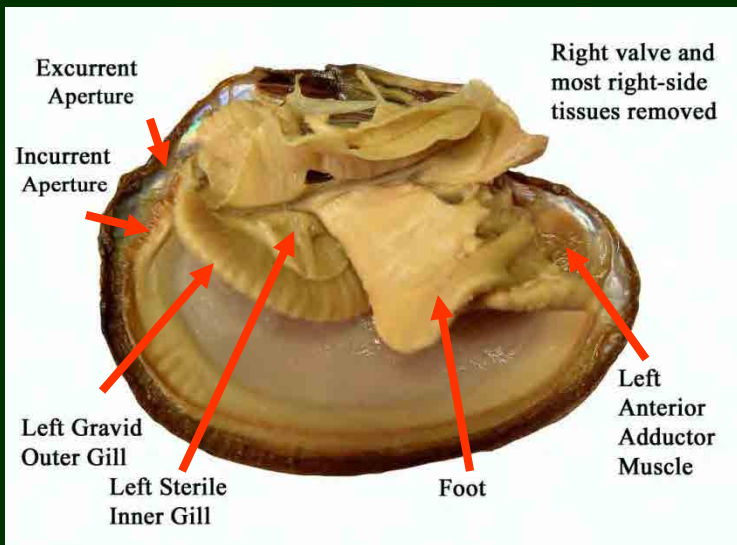
# VALUE OF MUSSELS TO HUMANS

- Used for human consumption....historically, but no longer.
- Shells used to make buttons...shell buttons replaced by plastics.
- Shells used for arts and crafts...harvest not significant.
- Shells used for pearl implant nuclei...yes, but other substitutes have been developed and demand has been low for years.
- Some produce gem-quality pearls...yes, but harvest level is minimal.
- Used for live bait...minimally, but other options are available.
- People depend on them for a living...in Texas, 13 or fewer people.
- Other economic value...not that we know.
- Medical value...not that we know.



# REPRODUCTIVE BIOLOGY - I

- Sperm is released, taken in by females, and eggs (fertile and unfertilized) and developing larvae are held in pouches (marsupia) on the gills.
- Larval mussels (glochidia) are parasites on fishes.
  - Released glochidia have only hours to find an appropriate host, attach in the proper location (gills, fins), or die.
  - When they transform to the juvenile stage and drop from the host, they must land on an appropriate substrate or die.



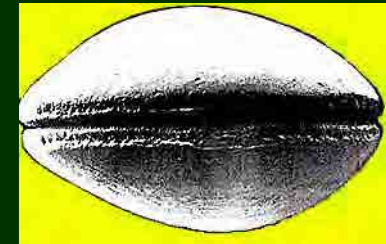
# REPRODUCTIVE BIOLOGY - II

- **MOST HAVE SEPARATE SEXES.**
  - Some species are hermaphrodites.
  - Sexes in some species are distinct.
- **GLOCHIDIA HAVE THREE FORMS:**
  - Hooked glochidia with large spines.
  - Apron or hookless glochidia.
  - Axe-head glochidia.



Female Male  
Texas Fatmucket (*Lampsilis bracteata*)

Hookless Glochidia



Hooked Glochidia



Axe-head Glochidia



Glochidia images in yellow were modified from SEM photos by M.A. Hoggarth



# REPRODUCTIVE BIOLOGY - III

Female mussels of several genera have mantle flaps (soft tissue extensions) or caruncles (worm-like extensions) that are used as lures to potential fish hosts.

Some combine glochidia into mucus packets called conglutinates that resemble worms, insects, or fish larvae.

Increased turbidity could prevent host fishes from finding female mussels.



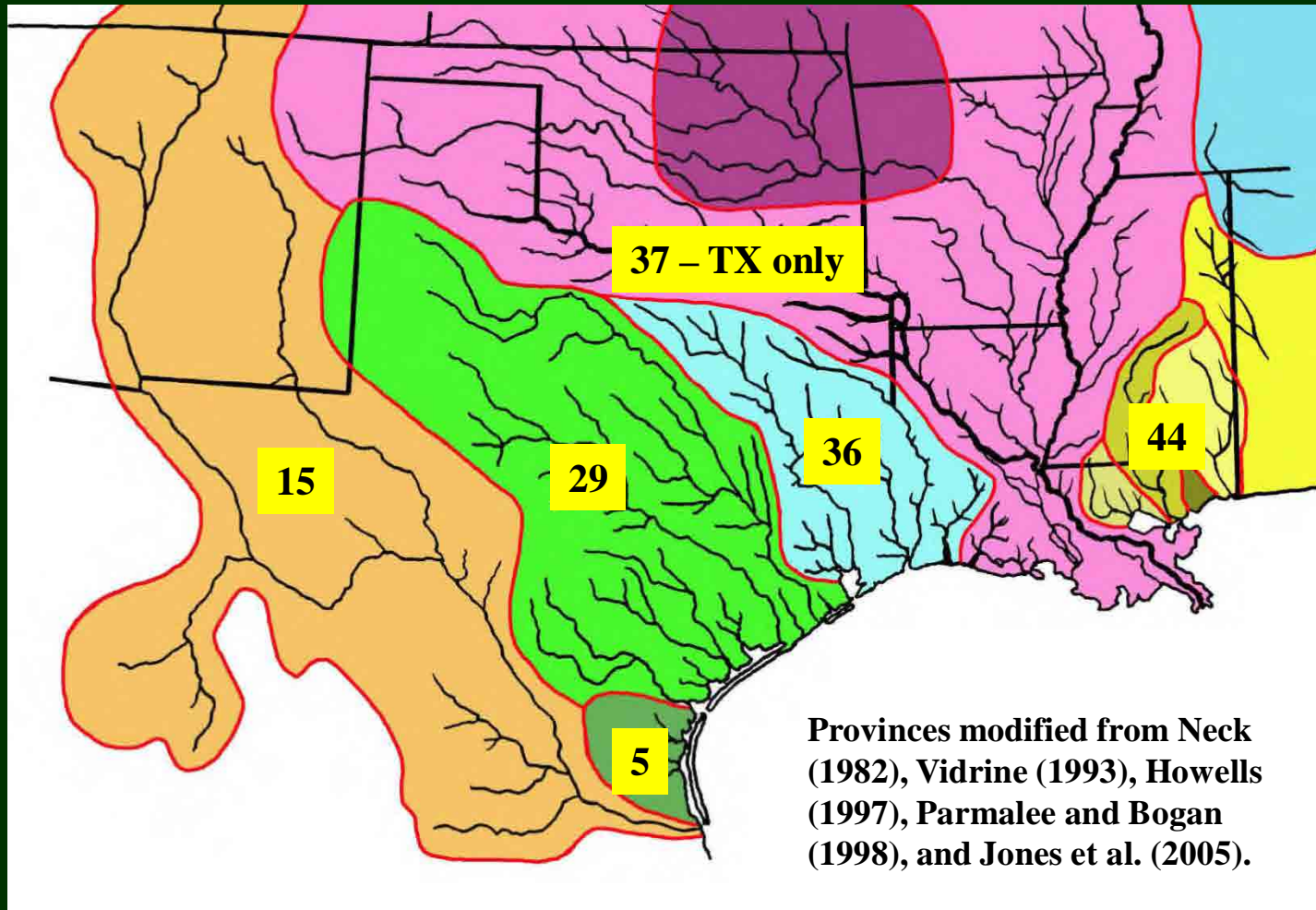
# FRESHWATER MUSSEL DIVERSITY - I

- The U.S. had the greatest diversity and abundance of freshwater mussels in the world.
- Some 300 species occurred in North America.
- Texas once supported at least 52 species.



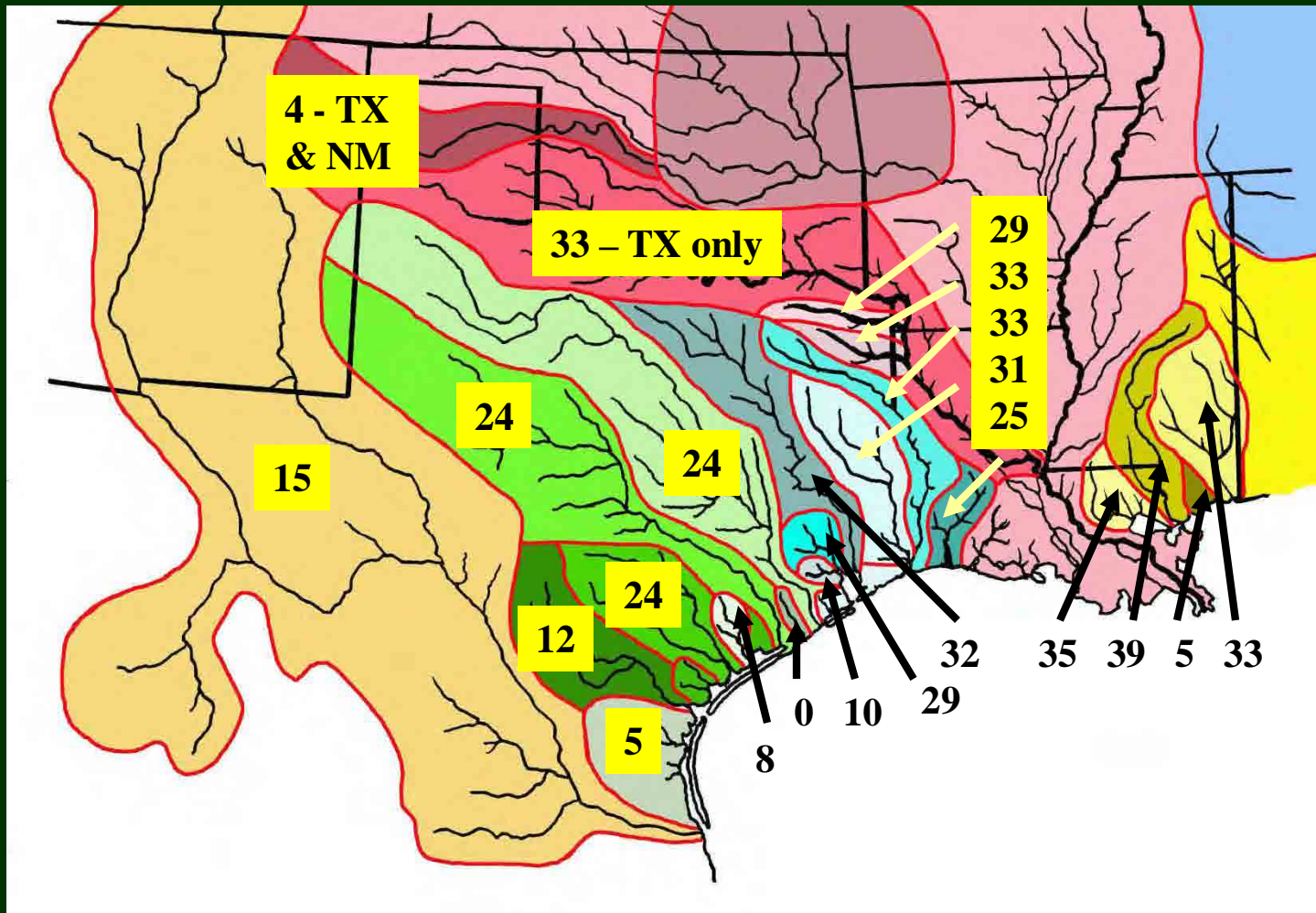
# MUSSEL SPECIES DIVERSITY – II

- By regional mussel provinces, mussel diversity is greatest in eastern & northeast Texas, but decreases toward the southwest.
- Numbers represent reported species (some may no longer exist).



# MUSSEL SPECIES DIVERSITY – III

- Mussel species documented by river system.
- Numbers represent reported species (some may no longer exist).



Howells  
(2010)

# DIVERSITY MEANS STABILITY!!!

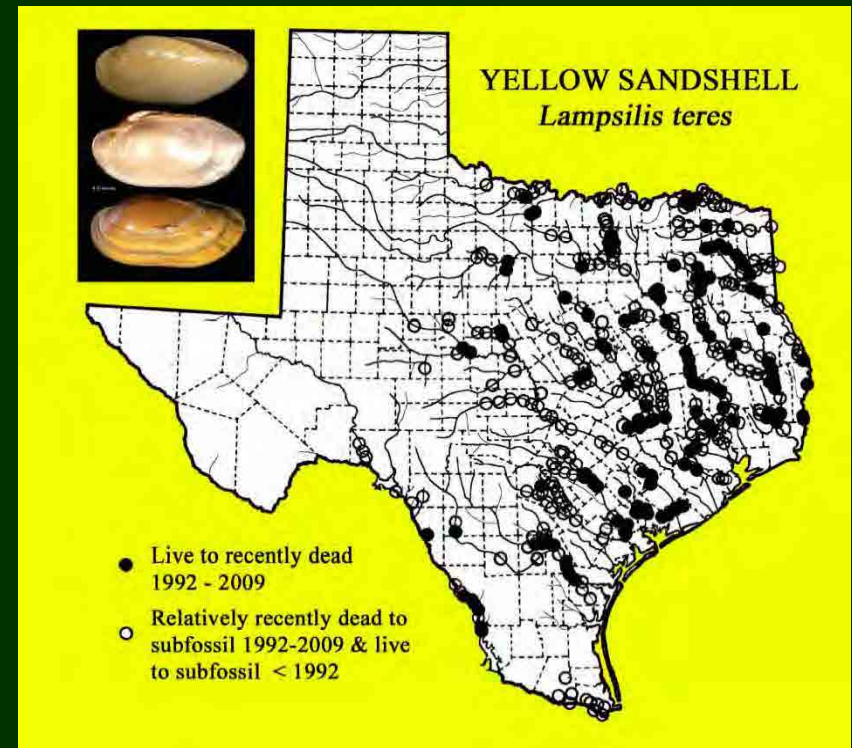
- The more complex an ecosystem is, the greater its stability.
- The more complex an ecosystem is, the more stress it can endure.
  - The more human abuse it can tolerate.
- Each time a species is lost, system stability is reduced.
  - The less human abuse it can tolerate before crashing.



# DECLINE IN FRESHWATER MUSSEL ABUNDANCE & DIVERSITY IN TEXAS

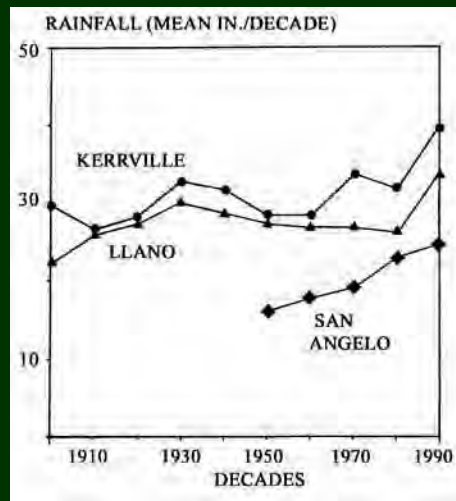
- Freshwater mussels are sensitive barometers of environmental quality; because of this sensitivity, they are heading toward extinction more rapidly than any other faunal group.
- Unfortunately, all species of native mussels have declined in abundance and distribution throughout Texas.
- Currently, about half our mussels are relatively secure.
- But, half have been dramatically reduced in abundance & distribution in recent years & are seriously at risk.

Yellow sandshell is one of the most widely distributed & abundant mussels in Texas, yet clearly has declined over much of its range in Texas waters.



# MAJOR REASONS FOR TEXAS MUSSEL DECLINES - I

- **Historic climate shift – becoming more arid over past 10-15,000 years**
- **Modern climate shifts**
  - **More rain falling now than 100 years ago (decade averages)**
  - **Pattern of fewer light & moderate showers, with long periods of drought punctuated with heavy damaging storms**
- **Poor historic land management**
  - **Overgrazing prior to 1900 caused increased runoff**



# MAJOR REASONS FOR TEXAS MUSSEL DECLINES - II

- **Reservoir construction – many rare mussels do not live in impoundments**
- **Mussel life cycle disruptions – many causes**
- **Point source & non-point source pollution**
- **Flow diversion & water retention practices**
- **General poor water management practices**
- **Rapid water level fluctuations**
- **Increasing salinity**
- **Channelization**



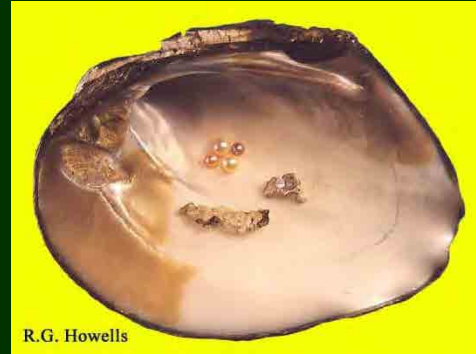
# MAJOR REASONS FOR TEXAS MUSSEL DECLINES - III

- **Riparian zone degradation**
- **General loss of terrestrial habitat**
- **General loss of aquatic habitat**
- **Bridge construction & repair**
- **Silt & sand deposition**
- **Headcutting**
- **General eutrophication**
- **Exotic aquatic plants**
- **Exotic carps & other exotics**
- **Public release of sensitive information**
- **Failure to communicate**
- **Poor professional advice**



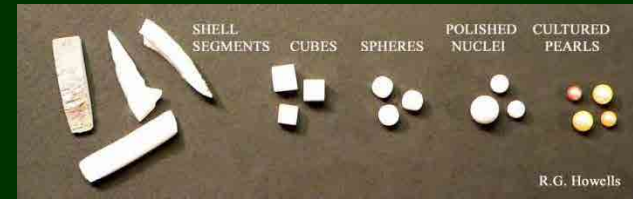
# MINOR REASONS FOR TEXAS MUSSEL DECLINES

- **Modern pearl harvest**
  - Intense harvest has occurred in limited areas
- **Shell collectors**
  - Known to focus on rare species
- **Boat and ship activity**
  - Commercial ship wake damage limited in Texas, but pleasure boats can damage habitat
- **Exotic tilapia**
  - High densities in some power-plant reservoirs have been linked to mussel reproductive failure



# MINIMAL AND NON-REASONS FOR TEXAS MUSSEL DECLINES - I

- Lack of host fishes – few local problems
- Historic aboriginal harvest – no evidence
- Historic shell button harvest – focused elsewhere
- Modern arts & crafts harvest – low level, sporadic
- Modern harvest for pearl implant nuclei (in Texas)
  - TPWD attempted to curtail the mussel fishery in 1997, but when musselers brought suit against the department, no evidence of harvest damage could be demonstrated, so 1992-1993 rules were reinstated
  - Commercial harvesters took only larger specimens of a few selected species
  - None of the rare species are primary commercial species
  - Restricted harvest regulations in 2006-2007 reflected lack of demand for mussel shells in Japan due to die-off of Japanese pearl oysters, few current license holders, & collapse of the mussel-harvest lobby



Cultured pearl production steps



Marine pearl oyster (above)



Drilled button shells

# MINIMAL AND NON-REASONS FOR TEXAS MUSSEL DECLINES - II

- **Asian clams (*Corbicula fluminea*, *Corbicula* sp.)**
  - Little or no evidence of harm to native mussels, but some competition must occur.
  - Disturbed environments favor Asian clam, but not native mussels.
  - Native mussels decline in disturbed environments, Asian clams are advantaged, so Asian clams may appear responsible.
- **South American armored catfishes (Loricariid catfishes) – Plecos**
  - These catfishes scrape algae from surfaces; mussels feed on plankton.
  - Texas introductions occur primarily in headwater springs & power plant reservoirs; mussels never occur in springs & no rare species occur in heated reservoirs.
  - These catfishes do compete with native snails and do damage banks in SE Texas, but no rare mussels occur in those waters.



# FUTURE THREATS TO TEXAS MUSSELS

- **Zebra mussel (*Dreissena polymorpha*) & quagga mussel (*D. rostriformis bugensis*)**
  - These Old World exotics invaded North America in the 1980s. Can harm & eliminate native mussels.
  - Zebra mussel invaded Lake Texoma (Red R.) and the upper Trinity R. system in 2009.
  - Basin water transfers are likely to help spread it.
- **Asian lake or golden mussel (*Limnoperna fortunei*)**
  - Not in North America, but likely to invade.
- **Harris mudcrab (*Rithropanopeus harrisii*)**
  - Native estuarine crab now invading inland.
- **Multiple researchers in the same area**
  - Efforts to coordinate field activities are limited.
- **Misinformation**
  - Even some biologists (often new to the field) are distributing misinformation.



# CAUTION: PROBLEMS WITH HISTORIC RECORDS

- **Historic descriptions of new species were vague, hard to obtain, & the range of shell variation & extent of species distributions were not well known... (there were no DNA labs at the time). So, many early records are flawed.**
- **Example - Specimens in the Singley collection (UT-Austin) include:**
  - **Among 59 specimens examined recently, 45.7% were misidentified and names needed to be updated on all.**
  - **Specimens labeled as Tampico Pearlymussel from the Colorado River at Austin were actually Golden Orb, a species from the Guadalupe-San Antonio and Nueces-Frio systems...The identification was definitely wrong and the location recorded was doubtful as well.**

**Tampico Pearlymussel**



**University of Texas material**



**Golden Orb**



# THREATENED AND ENDANGERED SPECIES

- A species can be biologically or ecologically threatened or endangered without being legally listed by state or federal agencies as threatened or endangered.
  - When terms like “threatened” or “endangered” are used, they may have no legal significance at all.
  - Note that various groups define these terms differently.
- At least one Texas mussel slipped into extinction without ever being legally listed as either threatened or endangered; another probably has; & others are getting close.

Rio Grande monkeyface (*Quadrula couchiana*) was found only in the Rio Grande. It was last seen near Brackettville in 1898. It now occurs only in museum collections or in fossil deposits.



# RARE MUSSELS IN TEXAS

- One species legally listed by USFWS as Federally Endangered (Ouachita rock-pocketbook) was also legally listed by TPWD as Endangered in the 1990s.
- In December 2009, TPWD listed 15 species as legally Threatened.
- Concurrently, USFWS began looking at 11 of these species
  - Three species were not included due to taxonomic status questions that were part of ongoing DNA analyses & two were already a candidates.
- Other Texas mussel species are also extremely rare, but have not been legally listed as such.
- Mussels that are legally listed in Texas include:

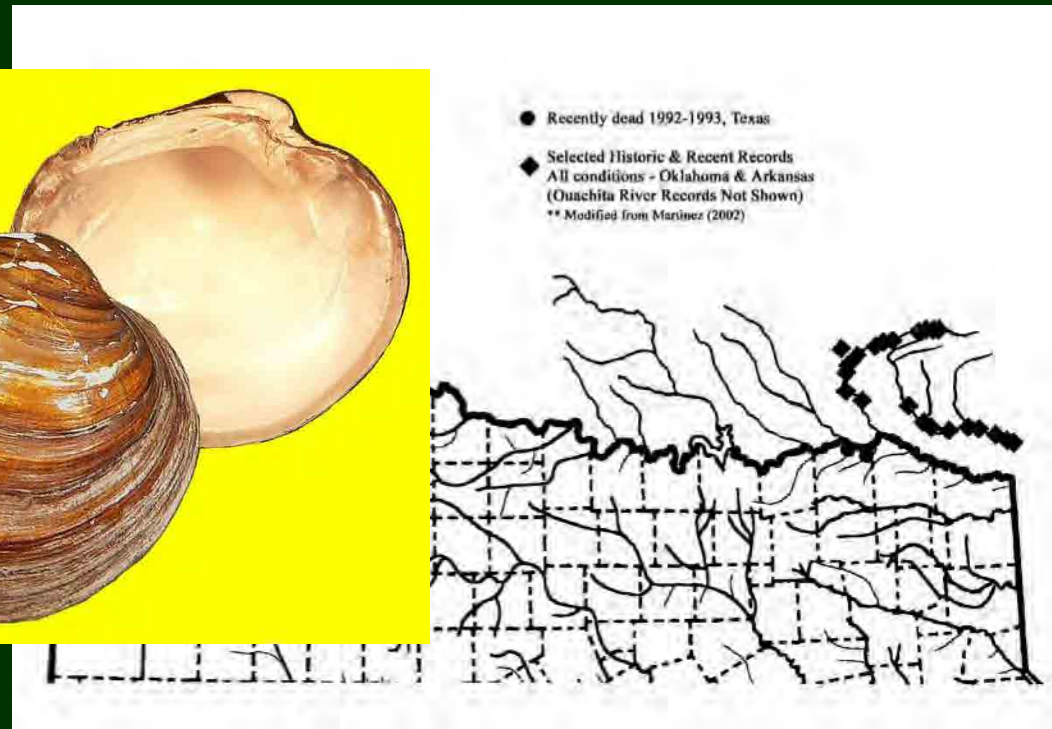
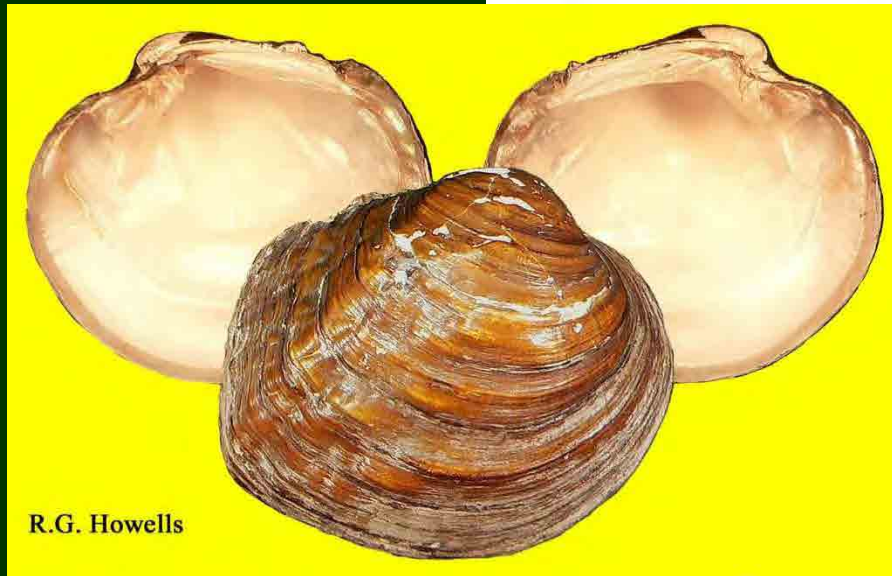


# OUACHITA ROCK-POCKETBOOK

## *Arkansia wheeleri*

### Endangered (legally) USFWS & TPWD

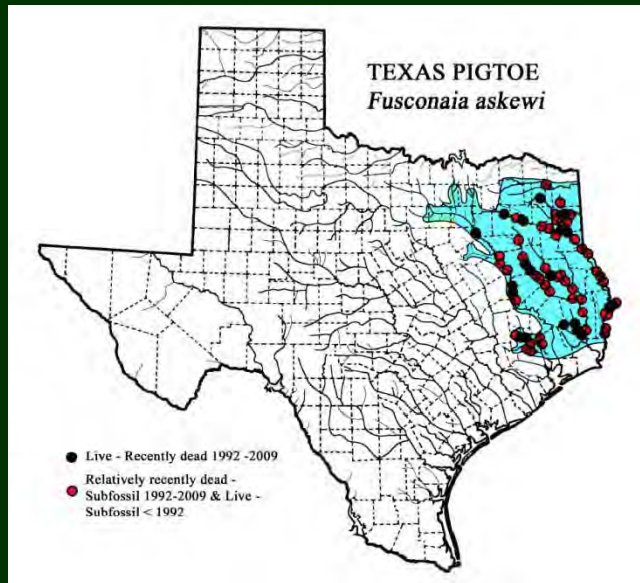
- Generally restricted to the Kiamichi R., OK, and Little River, OK/AR.
- One shell was found in each of two streams in Lamar Co., Texas, but no living populations are known to have been or to be present in Texas.



# TEXAS PIGTOE (*Fusconaia askewi*)

## Threatened (legally) TPWD

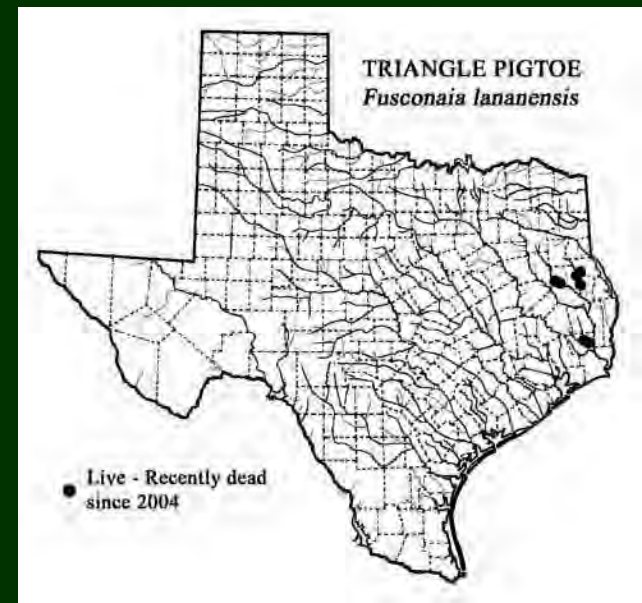
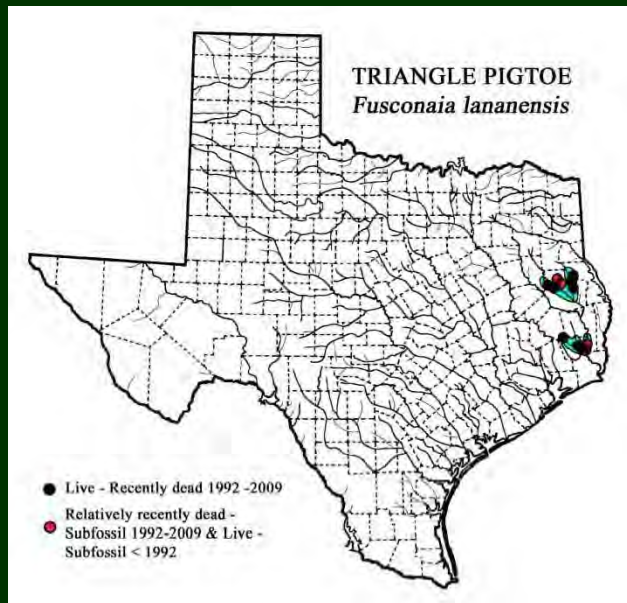
- Long believed to be rare in Texas, but new populations have been found in the past 5-6 years.
- Now known to persist in Big Cypress Bayou, the upper and lower Sabine R., upper Neches R., Central Angelina R., Village Creek (Neches drainage), and the West San Jacinto drainage.
- Moderate numbers occur in some waters, but few remain in others.



# TRIANGLE PIGTOE (*Fusconaia lananensis*)

## Threatened (legally) TPWD – Proposed USFWS

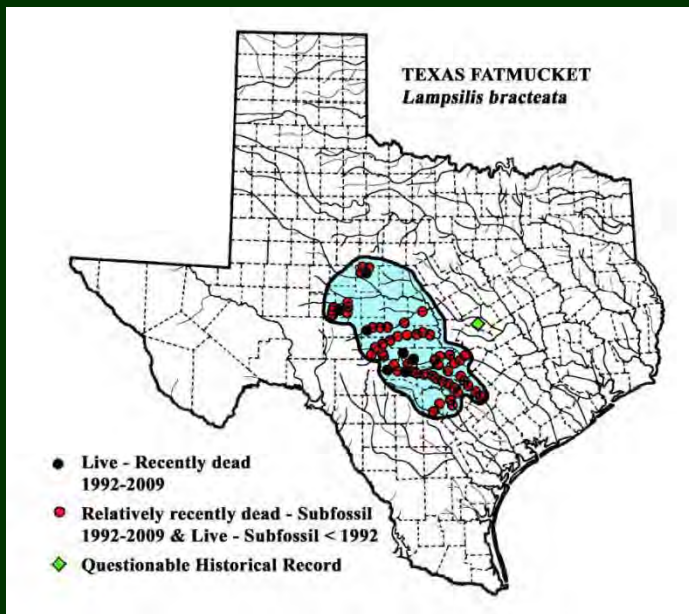
- Endemic to the Neches-Angelina drainage, Texas.
- Extirpated from the type locality, Lanana Creek at Nacogdoches.
- Survivors persist in the Angelina R., Attoyac Bayou and one tributary, and Village Creek (lower Neches R. drainage), but...
- (1) Genetic studies have failed to prove that is distinct from Texas pigtoe & (2) both are almost indistinguishable in the field.



# TEXAS FATMUCKET (*Lampsilis bracteata*)

## Threatened (legally) TPWD – Proposed USFWS

- Endemic to streams and small rivers of the Texas Hill Country & Edwards Plateau.
- Since 2004, only found alive in one stream in Runnels Co., one site in Menard Co., two sites in Gillespie Co., and one site in Kerr Co.
- A Tom Green County population was recently lost and survival of those in Runnels, Menard, and Kerr counties is doubtful.

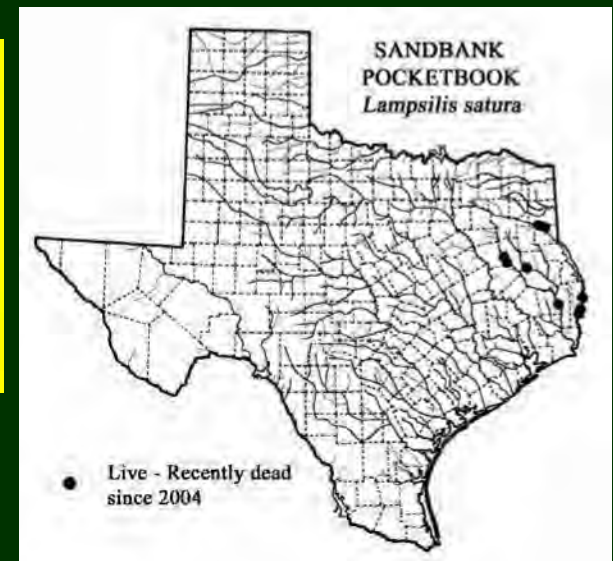
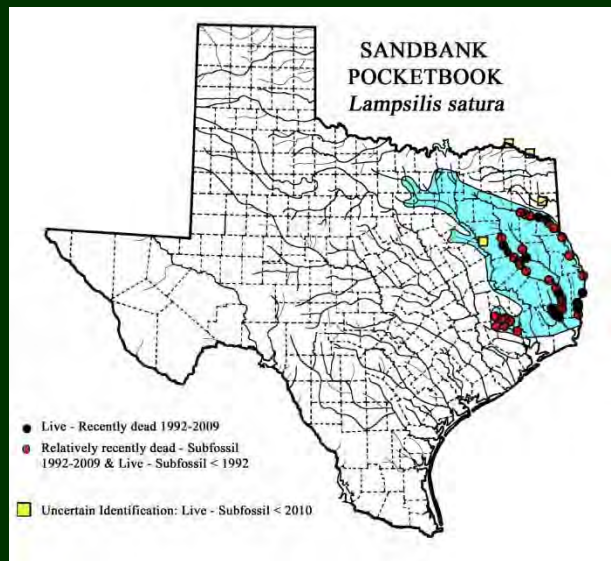


An additional population may be present in the Llano River (L.E. Burlakova, pers. comm.) but has not yet been formally reported.

# SANDBANK POCKETBOOK (*Lampsilis satura*)

## Threatened (legally) TPWD

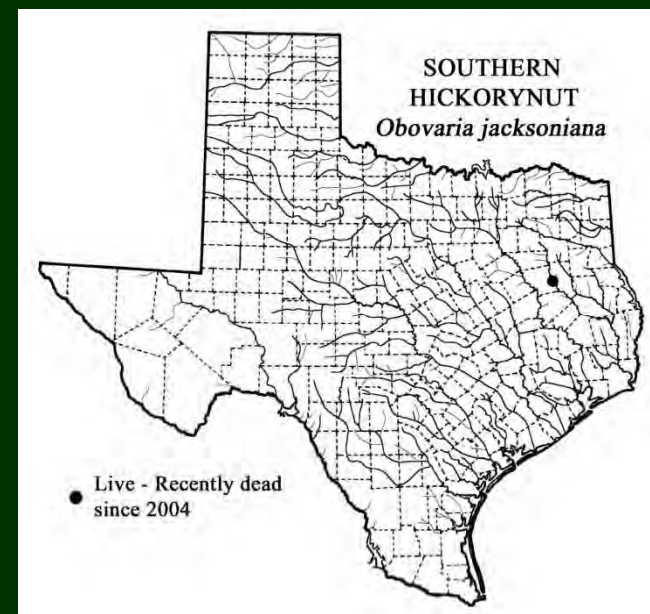
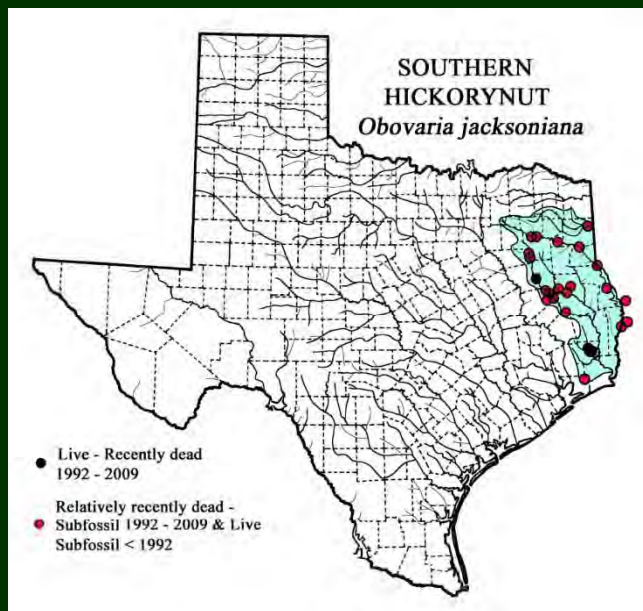
- Found in East Texas & southeast Louisiana.
- Small numbers remain in the upper & lower Sabine and Neches rivers.
- Apparently completely lost in the San Jacinto & Trinity rivers (questionable if it ever occurred in the Trinity River).
- The largest surviving population near Jasper was devastated in 2006.



# SOUTHERN HICKORYNUT (*Obovaria jacksoniana*)

## Threatened (legally) TPWD – Rejected USFWS

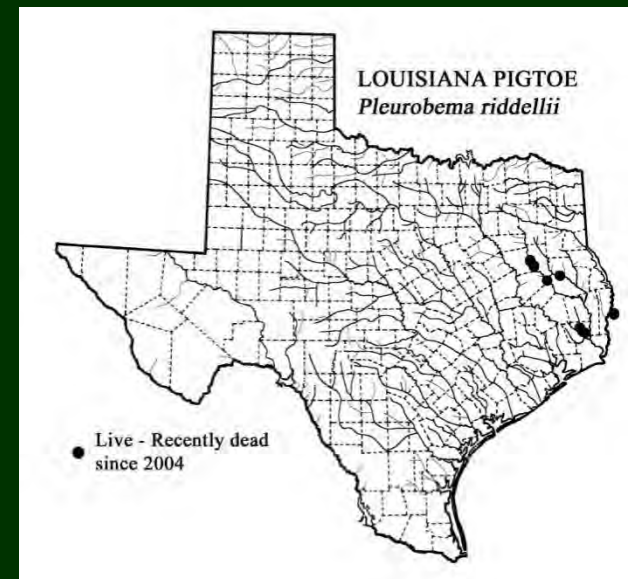
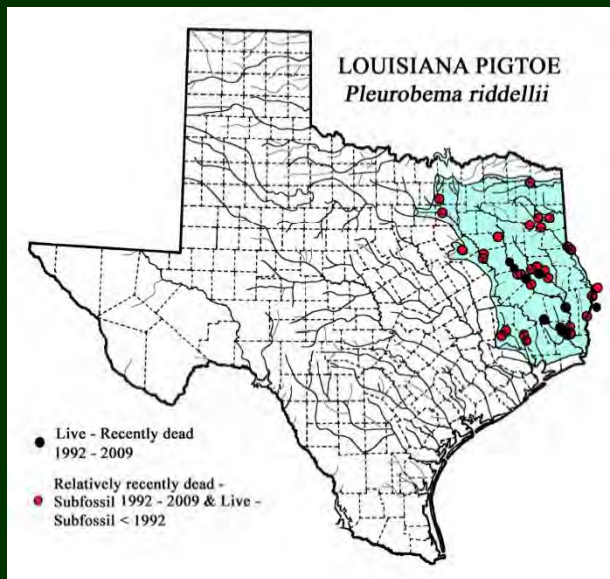
- Very rare in TX, MO, & TN, but more numerous in LA, MS, & AL.
  - USFWS rejected listing this species federally due to abundance in other states.
- Previously in the Big Cypress, Sabine, & Neches-Angelina systems in TX.
- In Texas, only seen alive at two sites in several decades and only found alive at one location since 2004.



# LOUISIANA PIGTOE (*Pleurobema riddellii*)

## Threatened (legally) TPWD – Proposed USFWS

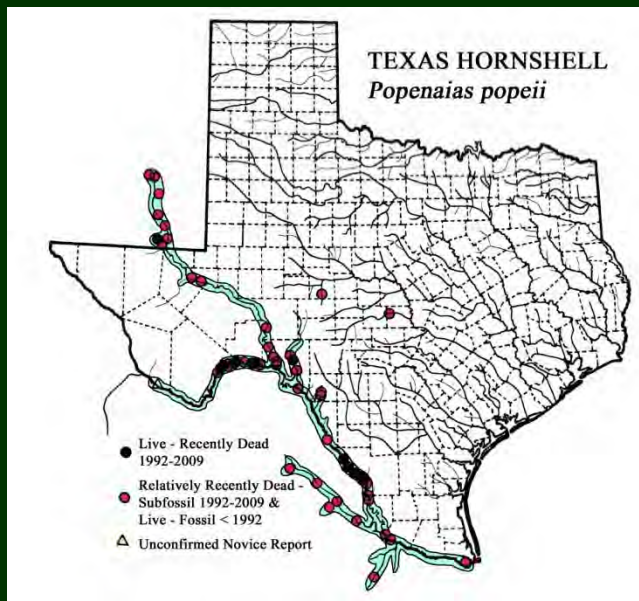
- Occurred in TX, LA, & apparently AR & OK.
- Occurred in East Texas in from the San Jacinto to the Sulphur River.
  - Never particularly abundant in Texas waters.
- Dramatically reduced in numbers in recent decades.
- Now small numbers have been confirmed in the upper & lower Neches-Angelina system & a Louisiana tributary of the lower Sabine River.



# TEXAS HORNSHELL (*Popenaias popeii*)

## Threatened (legally) TPWD – Candidate USFWS

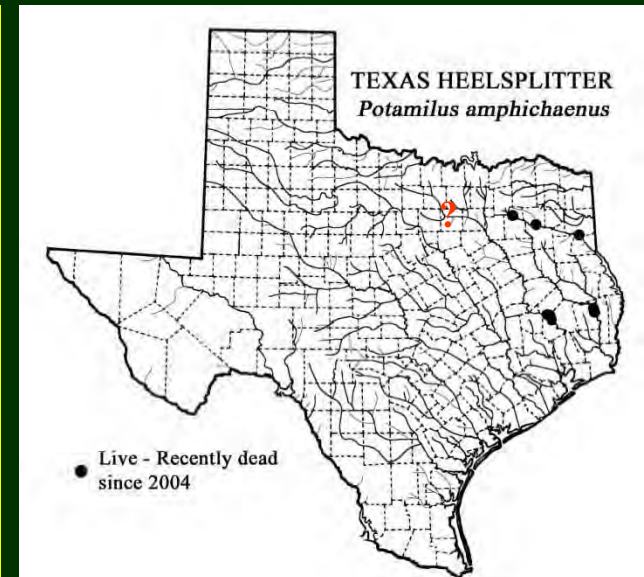
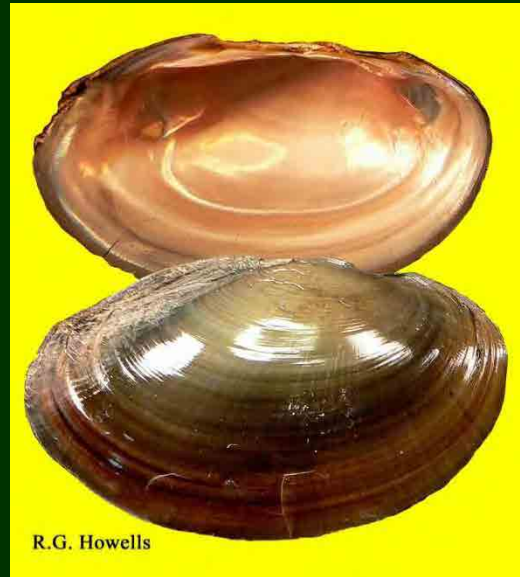
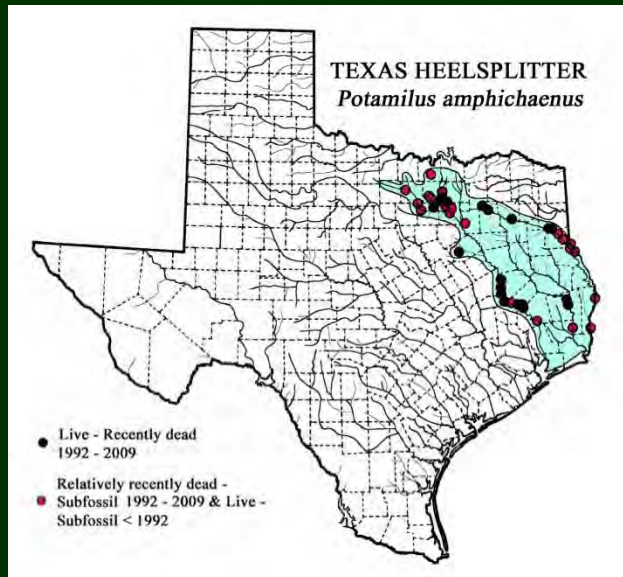
- Endemic to the Rio Grande & other systems in northeastern Mexico.
- U.S. populations have been reduced to small numbers in four areas: one site in NM, & the Devils River, an area of the Rio Grande between Big Bend and the Pecos River, & the lower Rio Grande in the vicinity of Laredo, Texas.
  - No populations appear to have been documented in Mexico in recent years.



# TEXAS HEELSPLITTER (*Potamilus amphichaenus*)

## Threatened (legally) TPWD – Candidate USFWS

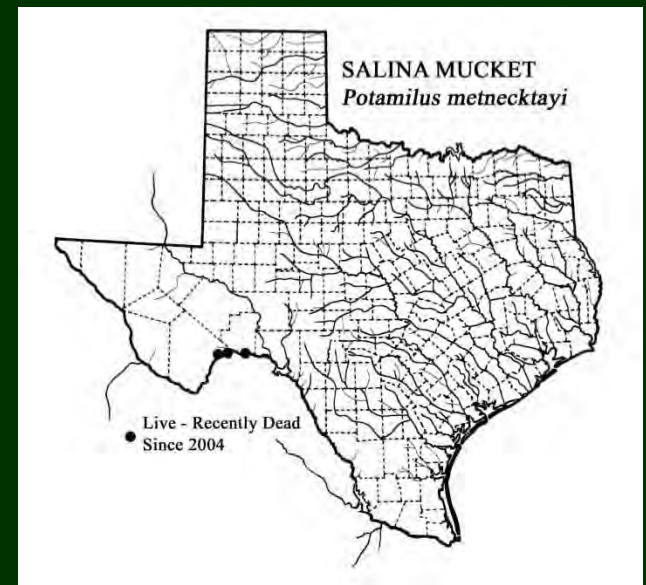
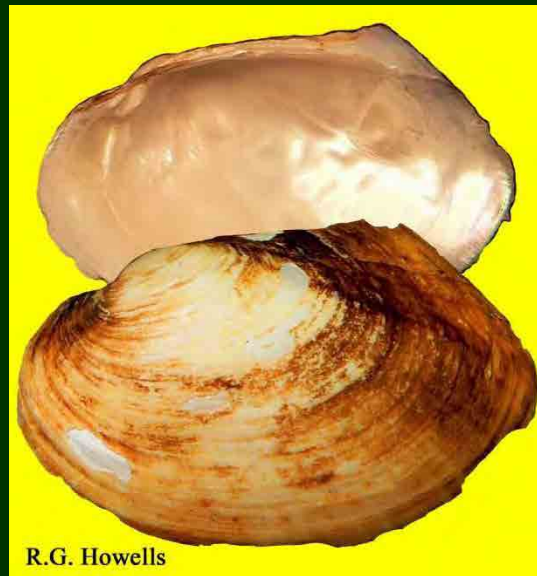
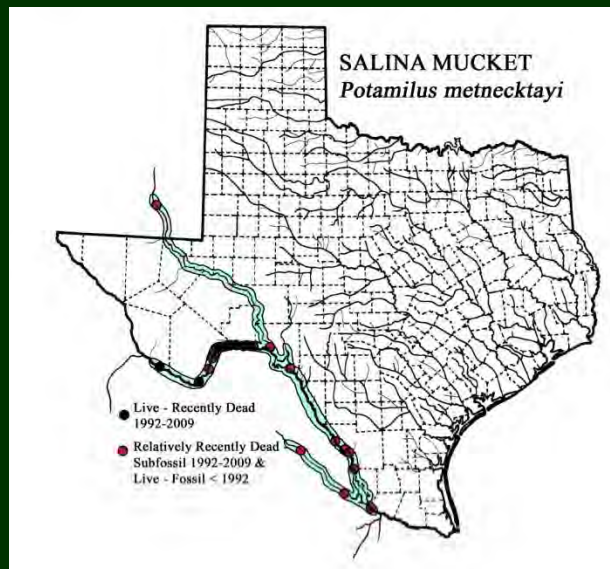
- Endemic to the Sabine, Neches-Angelina, and Trinity rivers.
- Small numbers remain in these systems. However,
- The largest population in the central Neches River was destroyed in 2006 when a reservoir was drained.
- Status in the upper Trinity River is questionable due to invasion by pink papershell (*P. ohiensis*); now many specimens appear to be intermediates that have not been positively identified.



# SALINA MUCKET (*Potamilus metnecktayi*)

## Threatened (legally) TPWD – Proposed USFWS

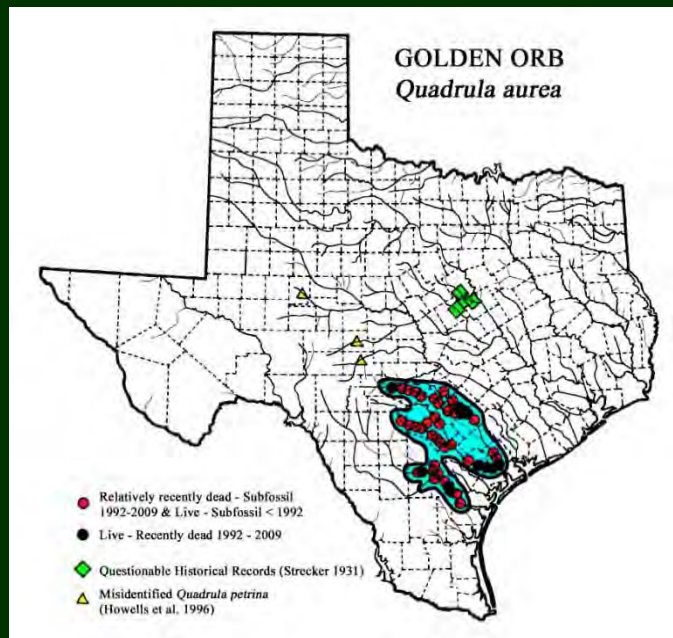
- Previously *Potamilus* & *Disconaias salinasensis*.
- Endemic to the Rio Grande, including the Pecos R. in the U.S. and Rio Salado in Mexico.
- Reduced to only a small number of living specimens in the Rio Grande between Big Bend and the Pecos River.



# GOLDEN ORB (*Quadrula aurea*)

## Threatened (legally) TPWD – Proposed USFWS

- **Endemic to the Guadalupe-San Antonio & Nueces-Frio systems.**
  - Reports from the Colorado and Brazos drainages are misidentifications, with a record from Austin in doubt.
- **Populations present in the lower San Marcos and central Guadalupe R. near Gonzales, the lower Guadalupe River near Goliad/Victoria, & Lake Corpus Christi, with a small group in the Guadalupe River in Kerr County apparently recently lost.**



R.G. Howells



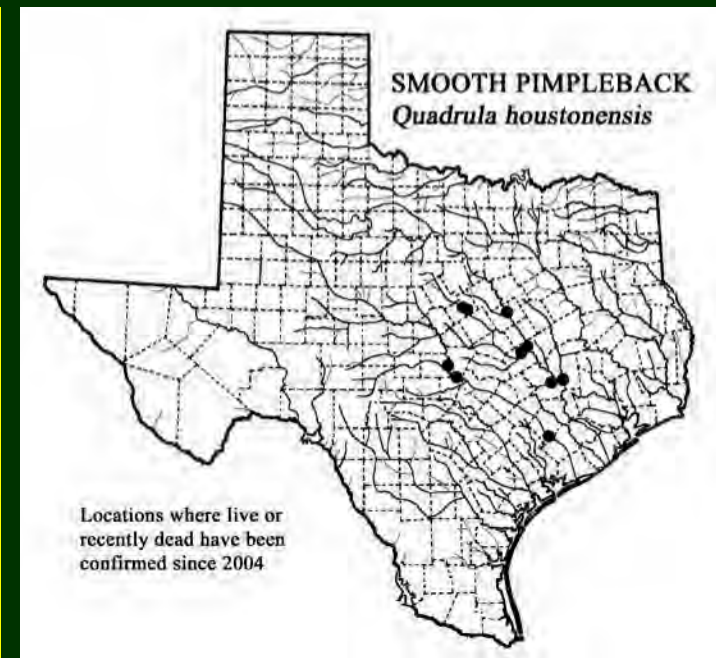
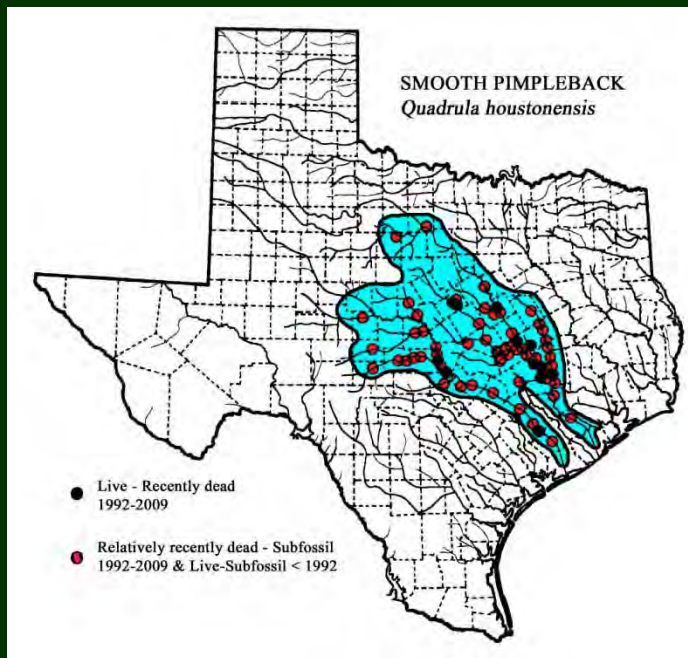
R.G. Howells



# SMOOTH PIMPLEBACK (*Quadrula houstonensis*)

## Threatened (legally) TPWD – Proposed USFWS

- Endemic to the Brazos and Colorado systems of Central Texas.
- Nearly eliminated from the Colorado, with small numbers in the Highland Lakes area and a site on the lower Colorado River.
- Recently found to be more numerous in the central Brazos River basin than long thought, but with some populations in obvious decline and the long-term status of others uncertain.

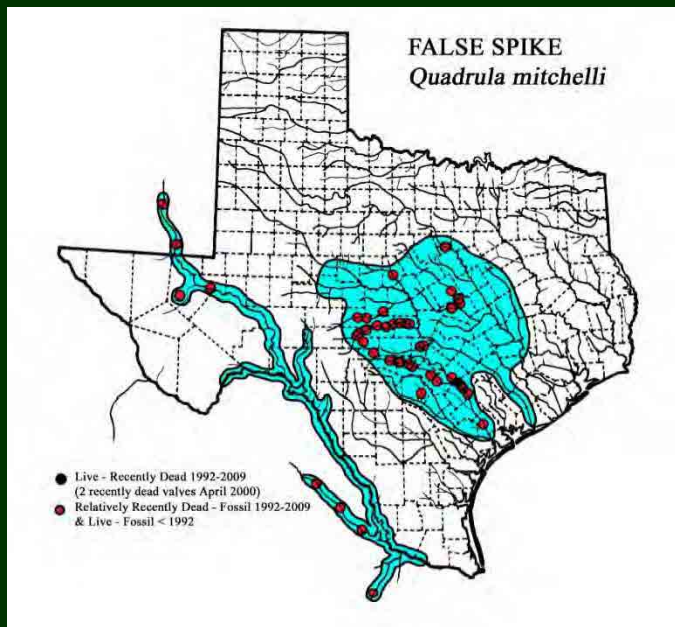


# FALSE SPIKE (*Quadrula mitchelli*)

## Threatened (legally) TPWD – Proposed USFWS

### Presumed extinct by the American Fisheries Society

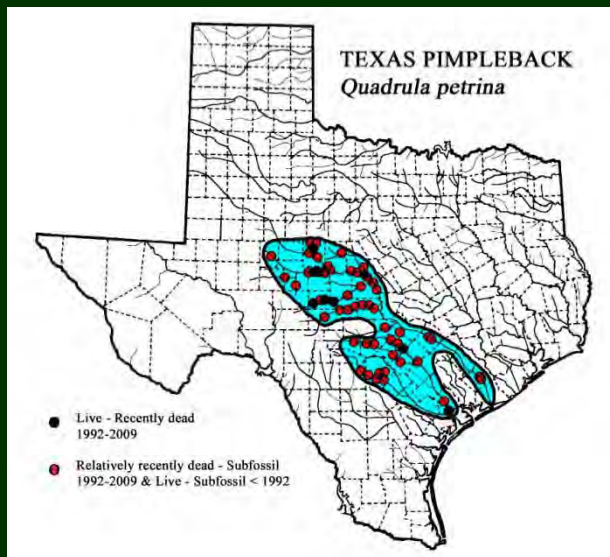
- Previously with populations in the Rio Grande and in Central Texas.
- Apparently never found alive in the Rio Grande & now extinct there.
- Not seen alive in Central Texas since at least the 1970s.
- Two recently dead valves were found in the San Marcos River in 2000, but several surveys since have failed to find any trace of it remaining.



# TEXAS PIMPLEBACK (*Quadrula petrina*)

## Threatened (legally) TPWD – Proposed USFWS

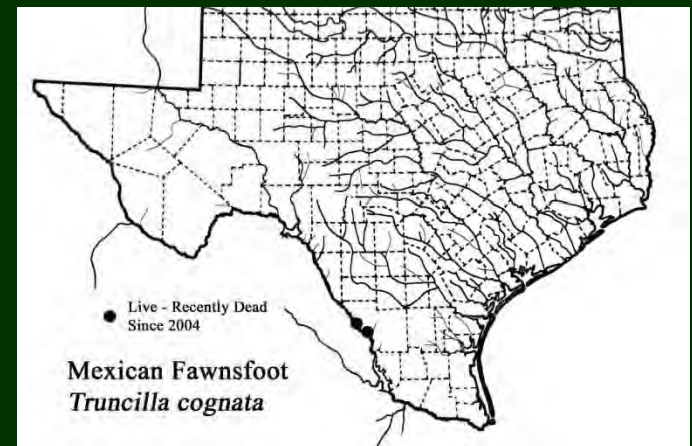
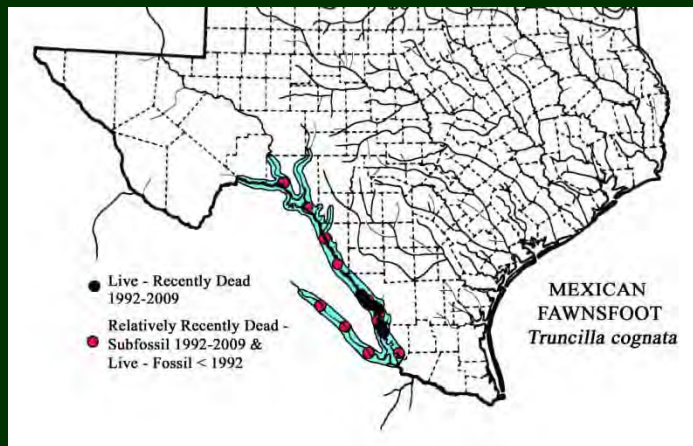
- Endemic to the Guadalupe-San Antonio and Colorado basins of Central Texas.
- Since 2004, this species has only been confirmed alive at two locations:
  - Lower Concho River – once the most abundant population known, but now threatened by upstream water retention and dewatering of its habitat.
  - Guadalupe River near Victoria - very few specimens found in 2009.



# MEXICAN FAWNSFOOT (*Truncilla cognata*)

## Threatened (legally) TPWD – Proposed USFWS

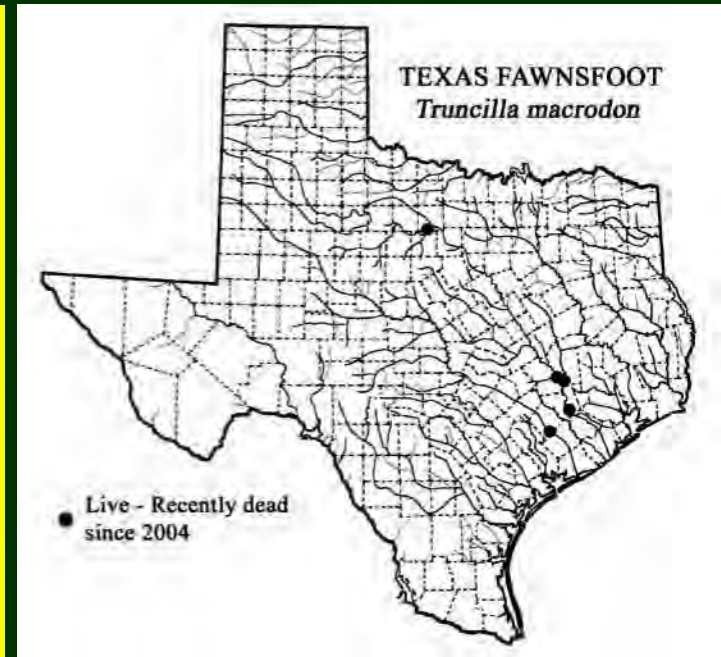
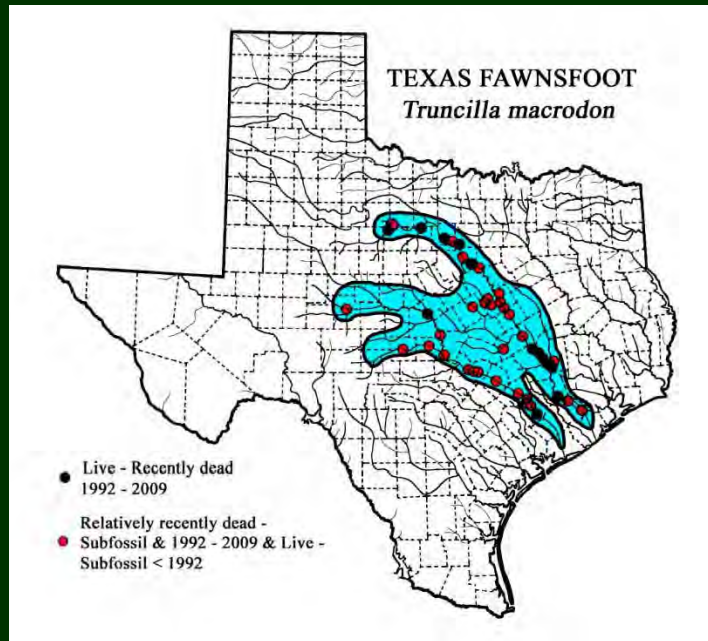
- Endemic to the Rio Grande, including Texas and Mexican tributaries.
- Found west of Del Rio in 1972, but since then known only from < 20 living or recently dead individuals found in a short stretch of the Rio Grande in Webb County, Texas.
  - This area is heavily impacted by NAFTA and Homeland Security activity & general degradation of the Rio Grande, with a proposed reservoir being considered that would eliminate most or all of the remaining survivors.



# TEXAS FAWNSFOOT (*Truncilla macrodon*)

## Threatened (legally) TPWD – Proposed USFWS

- Endemic to the Brazos and Colorado drainage of Central Texas.
- Relatively rare historically.
- Currently known only from several sites in the lower-central Brazos River & its tributaries, one location in the lower Colorado River, & with a few apparently surviving in the upper Brazos drainage.



# ADDITIONAL RARE MUSSELS IN TEXAS

- All are more numerous in other states, except one -

- Rock-pocketbook (*Arcidens confragosus*) - > 20 sites since 1980, but with few specimens; only major population destroyed in 2006
- Round pearlshell (*Glebula rotundata*) - > 12 sites since 1980
- Plain pocketbook (*Lampsilis cardium*) – 2-3 questionable historic reports
- White heelsplitter (*Lasmigona complanata*) - at 3 sites in Texas
- Rio Grande monkeyface (*Quadrula couchiana*) – apparently extinct
- Wartyback (*Quadrula nodulata*) – 7 sites since 1980; few recorded
- Pimpleback (*Quadrula pustulosa*) – 2 sites, if identification is correct
- Creeper (*Strophitus undulatus*) – 7 sites since 1980, none alive recently
- Fawnsfoot (*Truncilla donaciformis*) – 9 sites since 1980; few recorded
- Little spectaclecase (*Villosa lienosa*) – ca 20 sites since 1980, but declining in numbers and distribution



Rock-pocketbook



Round pearlshell



White heelsplitter



Wartyback



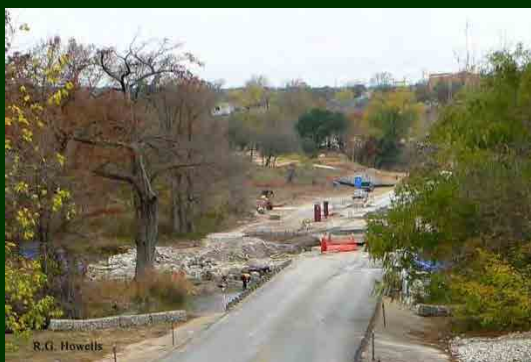
Creeper



Fawnsfoot

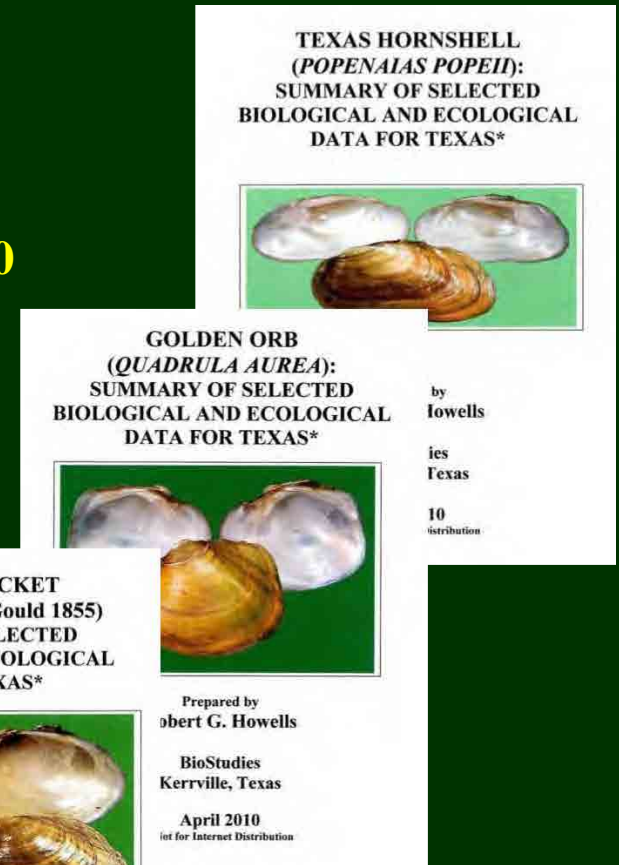
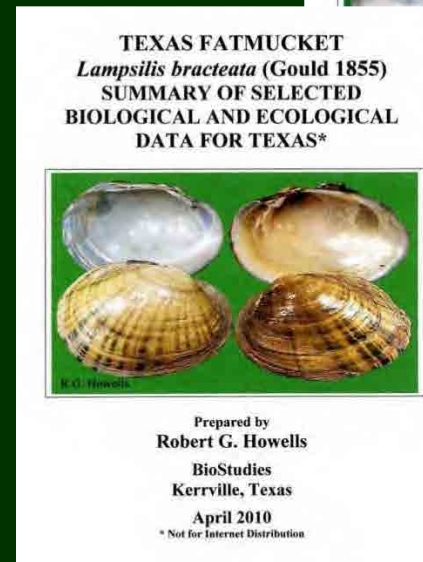
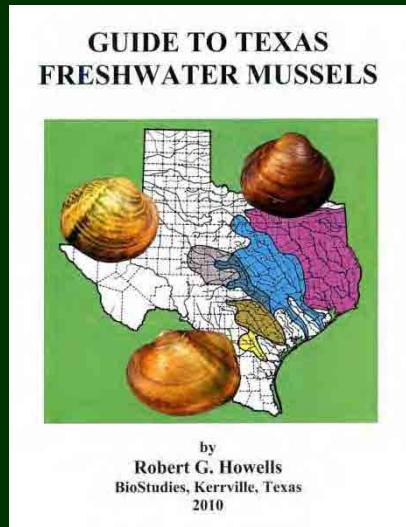
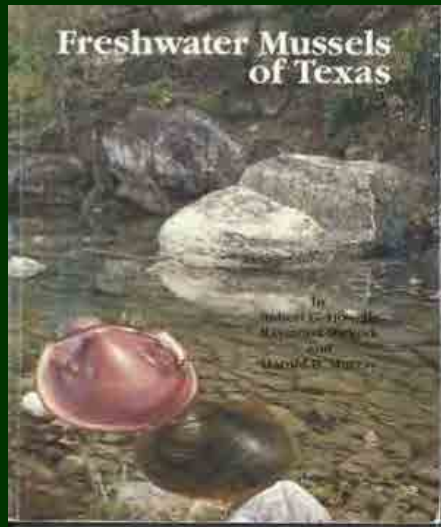
# BE AWARE

- Realities associated with threatened and endangered freshwater mussels may be a new concept in Texas...
- However, some other states have been dealing with rare mussel issues for several decades.
  - Methods to construct bridges over endangered mussel beds have been developed and applied.
  - Programs to find and relocate T&E mussels from construction and dredging sites have been used at many locations.
- This is not new and Texas is not alone.



# INFORMATION ON TEXAS MUSSELS

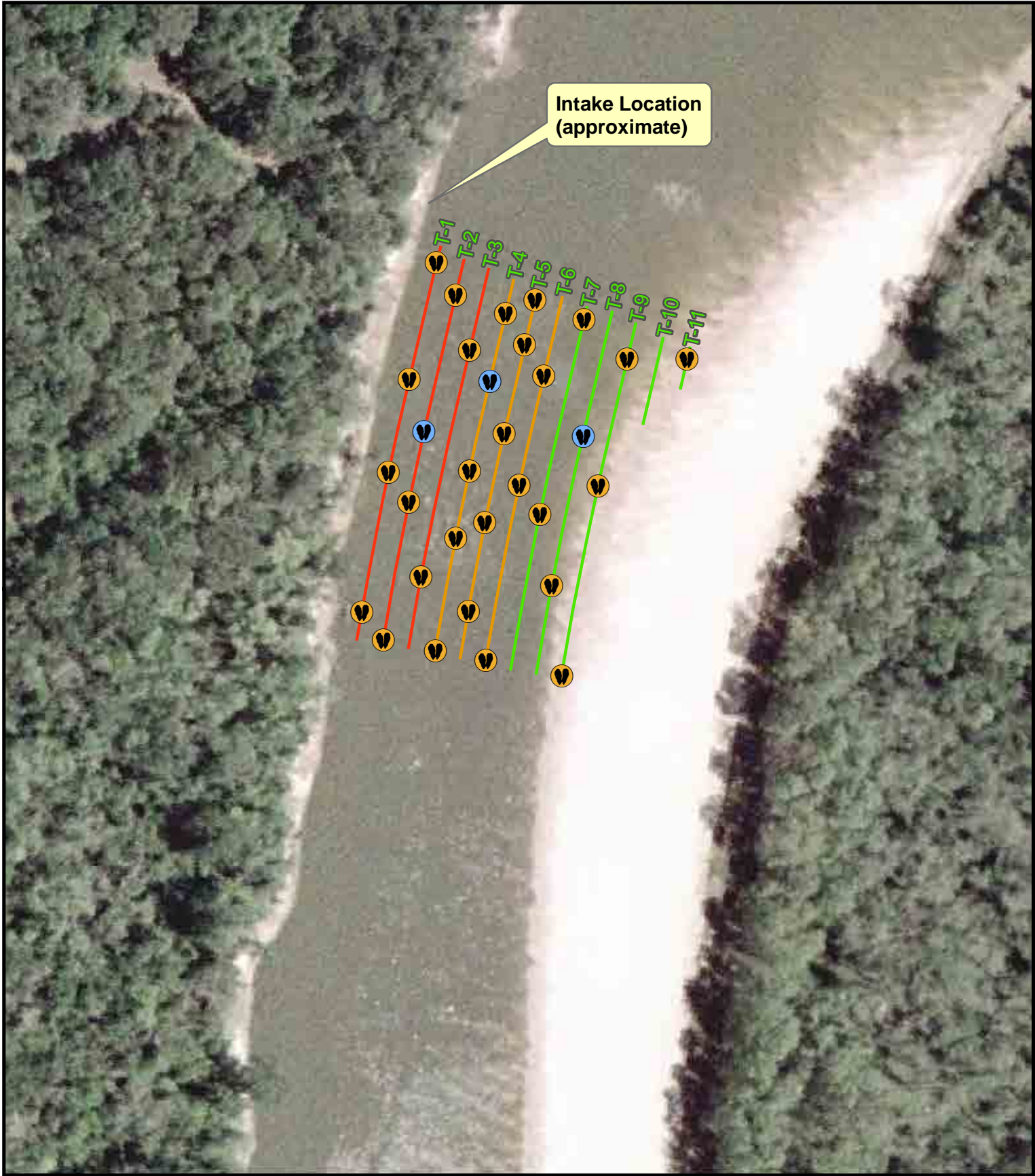
- **Freshwater Mussels of Texas – Howells et al. 1996**
  - From TPW Press, UT Press, Internet sources
- **Guide to Texas Freshwater Mussels – Howells 2010**
  - From the author
- **Biological and Ecological Data Reports – Howells 2010**
  - Reports on all 15 TPWD-listed threatened species
  - Funded by the Save Our Springs Alliance (Greater Edwards Aquifer Alliance), Austin, Texas



**WE CAN PRESERVE OUR RARE AND UNIQUE  
NATURAL RESOURCES FOR OURSELVES AND  
FUTURE GENERATIONS...**



**OR NOT**



Trinity River  
Capers Ridge Pump Station Inlet Location



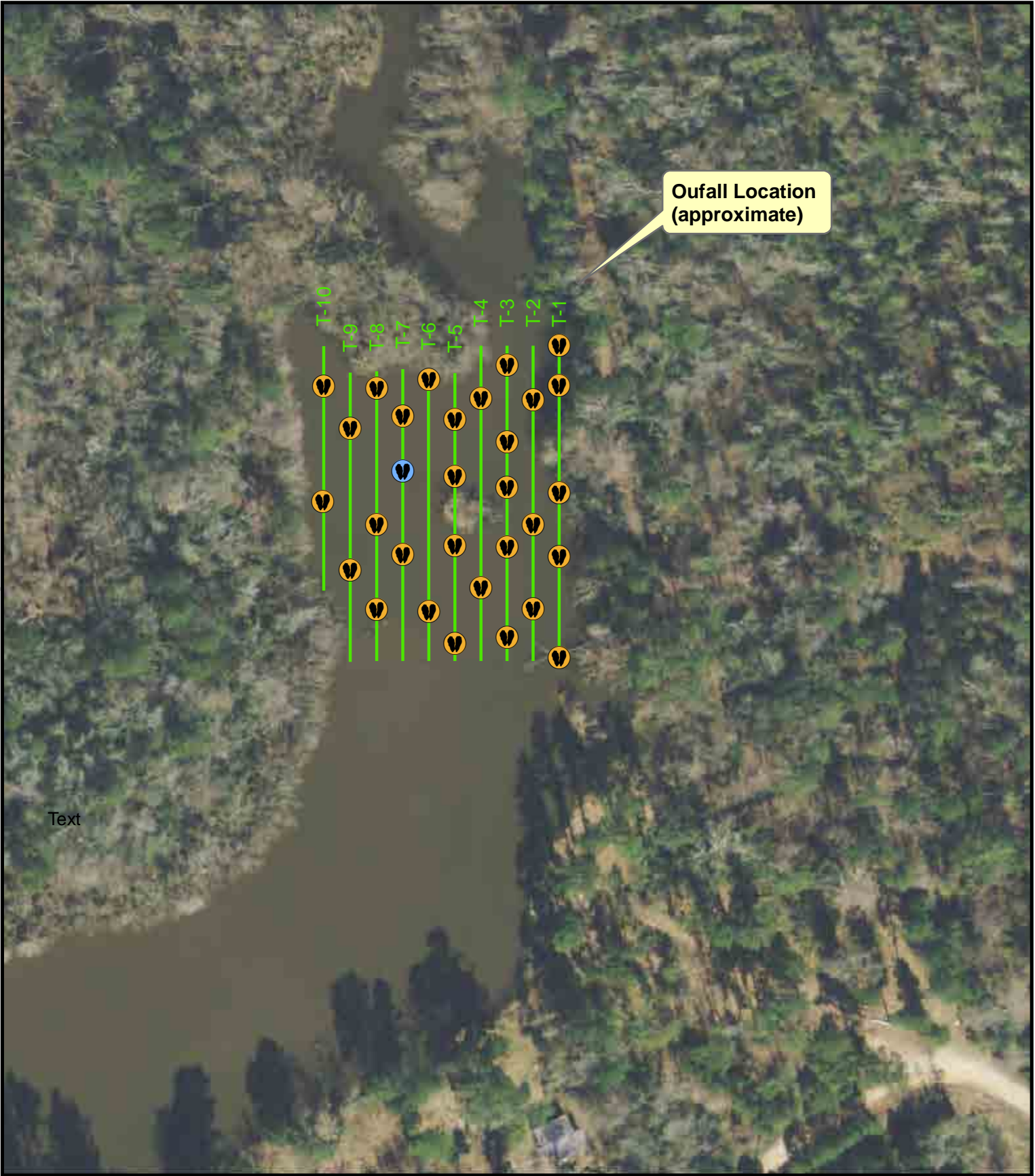
**Legend**

**Transects**

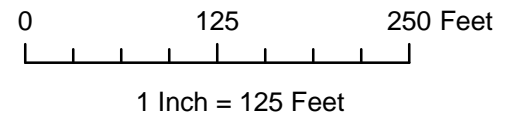
- 0-6' Depth
- 7-12' Depth
- 13-18' Depth

**Quadrats**

- Sample Location
- Water Quality Monitoring Location<sup>B - 1</sup>



East Fork of the San Jacinto River  
Luce Bayou Outfall Location



**Luce Bayou Transfer Project  
Freshwater Mussel and Habitat  
Characterization**

# **Risk Analyses for Establishment of Dreissenid Mussels at Selected Stations in the Watersheds of the San Jacinto and Lower Trinity Rivers**

Prepared for:

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January 10, 2012

# Risk Analyses for Establishment of Dreissenid Mussels at Selected Stations in the Watersheds of the San Jacinto and Lower Trinity Rivers

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## Executive Summary

AECOM requested a review of water quality data developed by Espey Consultants (EC), Inc. (2011) for the City of Houston and Coastal Water Authority relative to the potential for dreissenid mussels (i.e. zebra mussel, *Dreissena polymorpha*, and quagga mussel, *Dreissena rostriformis bugensis*) to establish sustainably reproducing populations in portions of the drainage basins of the San Jacinto and lower Trinity Rivers and Lake Houston. They also requested an analysis of the potential impact for dreissenid mussels to be introduced to isolated watersheds by interbasin water transfers, particularly to Lake Houston by water transfer from the Trinity River. Relevant data on surface water temperature regime, pH, calcium concentration, and oxygen concentration were reviewed to develop risk assessments for dreissenid mussel establishment at 11 sampling stations within these watersheds and for potential hydrological transport of mussel planktonic larvae (i.e., veligers) between them, especially between the Trinity River and Lake Houston via a proposed water diversion if Lake Livingston became infested with zebra mussels.

Analysis of water quality data indicated that nine stations (see Figure 1) had either moderate (Stations: EC\_CWALynch, EC\_CWAMid, EC\_CWATRPS, and EC\_LuceBayou) or high probabilities (Stations: EC\_WestFork, EC\_NEWPP, EC\_Lake Houston\_B1, EC\_Lake Houston\_B2 and SWQM\_10896) for supporting sustainably reproducing zebra mussel populations. Only stations EC\_Trincaper on the Trinity River and EC\_WestFork on the West Fork of the San Jacinto River appeared to have a low probability for establishment of zebra mussel populations based primarily on mid-summer water temperatures exceeding the mussels' incipient upper thermal limit of 32°C (See Figure 1). In contrast, none of the 11 stations on the San Jacinto River or lower Trinity River drainages appeared capable of supporting sustainably reproducing quagga mussel populations because their mid-summer water temperatures exceeded this species' incipient upper thermal limit of 28°C. Thus, while the examined waterbodies, rivers and canals appeared to be resistant to quagga mussel invasion, most of them with the possible exception of the East Fork/Caney Creek arms of the San Jacinto River Drainage appeared capable of supporting zebra mussel populations.

If zebra mussels become established in Lake Livingston, mussel larvae carried downstream in the lower Trinity River could be transported to Lake Houston via the proposed Luce Bayou Interbasin Transfer Project (LBITP) from the Trinity River to Lake Houston. In contrast, if Lake Houston became infested with zebra mussels, diversion of water to the lower Trinity River is likely to result only in populations of low density as larvae would be carried downstream into Trinity Bay. While mid-summer surface water temperatures at the EC\_LuceBayou intake may be too high to support a zebra mussel population, mussel spawning and presence of settlement competent mussel larvae would occur at cooler temperatures (12-24°C) allowing larval transport through a water diversion system to Lake Houston. Lake Houston has surface water temperature, pH, calcium concentration and dissolved oxygen regimes which make it likely to support a sustainably reproducing zebra mussel population. Similarly, establishment of a zebra mussel population in Lake Conroe on the West Fork of the San Jacinto River could also lead to downstream transport of mussel larvae into Lake Houston. Larval transport from the Trinity River through the Coastal Water Authority (CWA) Canal could cause zebra mussel infestation of Lynchburg Reservoir which, based on EC\_CWALynch water quality data, appears to have a moderate probability of supporting a sustainably reproducing mussel population.

Because of the potential vulnerability of much of the San Jacinto and lower Trinity River watersheds to zebra mussel infestation and the potential for zebra mussels to be transferred from mussel-infested portions of Lake Texoma to nearby waterbodies on the upper reaches of the Trinity River watershed, it may be important to initiate periodic mussel monitoring at the 11 examined stations and at other relevant sites including Lakes Conroe and Livingston. Monitoring should include examination of plankton net tow samples<sup>1</sup> for the presence of zebra mussel larvae and deployment of mussel settlement monitors during the spring and fall when water temperatures (18-24°C) are most suitable for zebra mussel reproduction and settlement. In addition, hard surfaces at selected sites could be periodically examined by divers for the presence of adult mussels.

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<sup>1</sup> Net tow sampling is a process whereby plankton is collected with a net made of fine mesh. The net is lowered into the water to a specified depth and then retrieved vertically or towed behind the vessel for a period of time and depth thus sampling a specific oblique depth of the water column. (NOAA, 2012)

## 1.0 Introduction

This report was prepared in response to a request from AECOM to review the potential for dreissenid mussels (i.e. zebra mussel, *Dreissena polymorpha*, and quagga mussel, *Dreissena rostriformis bugensis*) to establish sustainably reproducing populations in portions of the drainage basins of the San Jacinto and lower Trinity Rivers and Lake Houston. AECOM provided water quality data on these watersheds developed by Espey, Inc. (2011) for the City of Houston and Coastal Water Authority. Data on surface water temperature regime, pH, calcium concentration, and oxygen concentration were reviewed for 11 stations within the watersheds of the San Jacinto and lower Trinity Rivers (locations of the 11 stations can be seen on Figure 1) from which risk probabilities were determined for either zebra or quagga mussels developing sustainably reproducing populations. These four water quality parameters were chosen for development of risk assessment for mussel population development because they are generally considered to most determine environmental suitability for both species (Claudi and Mackie 1994; McMahon 1996). Also examined was the potential for hydrological transport of planktonic mussel larvae (i.e., veliger larvae) between the watersheds of the San Jacinto and lower Trinity Rivers and Lake Houston via water diversions.

## 2.0 Habitat Requirements

Freshwater mussels in Texas occur in still waters or those of moderate flows, including rivers and streams, lakes, reservoirs, ponds, and canals. They live within a variety of substrate types, but most frequently firm mud, stable sand, and gravel, including combinations of these types, and in relatively shallow water to depths of many meters. Within such habitat conditions, the most limiting factor for fresh mussels is the lack of dissolved oxygen. Many mussels tolerate wide ranges in water temperatures as long as extremely hot or cold extremes are avoided and annual fluctuations support normal breeding activity. Freshwater mussels usually require environments that are very stable over long periods of time, with changes to their environments, including modifications to terrestrial ecosystems, resulting in an intolerant environment for the mussels. (Howells, 2009)

Habits in which freshwater mussels do not thrive include deep shifting sand (slow moving mussels cannot maintain positions in rapidly moving substrates), deep soft silt (they may sink and smother), scoured cobble and bedrock (where they cannot dig or may be easily swept away), server long-term dewatering due to drought or drawdown (that exposes mussels to temperature extremes desiccation, precludes feeding, etc), dramatically fluctuating water levels (mussels move slowly and cannot respond quickly), dense beds of aquatic macrophytes (that confound digging into the substrate, reduce phytoplankton food sources, and may be oxygen deprived at times), substrates covered with algal layers or sticks and leaves (confound movement, may block feeding and breathing), low-quality polluted waters (many are very intolerant of pollution), saline waters (only two species tolerate even minimal levels of salinity), lack of host fishes (that are necessary for reproduction), and for some species impounded waters (many species require flowing waters and cannot survive in reservoir conditions). (Howells, 2009).

It is important to minimize impacts to freshwater mussel habitat where possible to allow for mussels to thrive and reproduce. As well as the habitats described above, silt-laden turbid waters, (that can clog gills or preclude host fishes seeing female lures or conglomerates contacting glochidia), and unstable banks

(which can fall and cover mussels resulting in an unsuitable mussel habitat) can also result in adverse impacts for mussels. (Howells, 2009)

### **3.0 Bases for Risk Assessment of Probabilities for Establishment of Sustainably Reproducing Dreissenid Mussel Populations**

The adaptations of *D. polymorpha* (zebra mussel) and *Dreissena rostriformis bugensis* (quagga mussel) to abiotic environmental factors are relatively similar. This is not unexpected as the two species are closely related congeners (Stepien et al 2002; Orlova et al. 2005; Albrecht et al 2007) estimated to have diverged 221,000 ±78,000 years ago (Stepien et al 2002). Thus, there has been relatively little time for the evolution of distinctly different physiological adaptations between them. However, where good comparative data exists, they have revealed subtle differences in these species' adaptations to physical factors that could impact their ability to develop sustainably reproducing populations in the examined stations on the watersheds of the San Jacinto and lower Trinity Rivers and in Lake Houston. The most important physical factors for sustaining reproducing populations of zebra and quagga mussels are generally agreed to be summer surface water temperatures, calcium concentration, pH, and dissolved oxygen concentration (Claudi and Mackie 1994; McMahon 1996). It was these four factors that were extracted from physical surface water data provided by AECOM to assess the probability for dreissenid mussel population establishment at the selected stations. Inspection of Table 1 indicates that there are far more data available on the physiological adaptations to these four abiotic factors for zebra mussels relative to quagga mussels. But where comparative data exists, conclusions were drawn regarding the potential risk of each species to establish sustainably reproducing populations in the 11 sites for which AECOM provided water quality data.

#### **3.1. Temperature Tolerance**

Studies indicate that zebra mussels appear to have a somewhat higher incipient (i.e., long-term) upper thermal limit (29-32°C) than quagga mussels (28°C) (Table 1). Their greater thermal tolerance may allow them to be more successful in the warm shallow water habitats characteristic of the lower Trinity River and Lake Houston where surface water temperature at depths of <1.5 m reach or exceed 30°C during summer months. A lower incipient upper thermal limit may be the main factor that has prevented quagga mussel colonization of the lower Mississippi River where zebra mussels have become well established (United States Geological Survey 2011a, 2011b). The temperature limits for zebra mussel larval development to a settled juvenile stage are 12-24°C but the same data are unknown for quagga mussels (Table 1).

The upper temperature limit for spawning by both species is 24°C, but quagga mussels may initiate spawning at a lower temperature of 9°C while zebra mussels initiate spawning at >12°C (Table 1). Peak spawning in both species occurs between 18-24°C. The temperature range for larval development is 12-24°C in zebra mussels, and is unknown but likely similar in quagga mussels (Table 1). For this reason, zebra mussel spawning/settlement seasons in Lake Texoma, Texas, are limited to spring and fall periods separated by summer cessation of spawning and settlement when water temperatures exceed 24°C (McMahon, unpublished data). This is also likely to be the case if zebra mussel populations become established in the watersheds of the San Jacinto and lower Trinity Rivers.

### **3.2. Calcium Requirements**

Published studies indicate that zebra mussels require calcium concentrations that are  $\geq 8$ -12 mg Ca/L (Hincks and Mackie 1997; Mellina and Rasmussen 1994) and for quagga mussels,  $\geq 12$  mg Ca/L (Jones and Ricciardi 2005) (Table 1). However, 12 mg Ca/L is the generally accepted lower limit for both species (Whittier et al, 2008) and was, thus, used as the lower limit for developing colonization risk assessments for both species in the watersheds of the San Jacinto and lower Trinity Rivers.

### **3.3 pH Requirements**

Studies indicate that the tolerated incipient pH range for zebra mussels is 6.0 to 8.5-9.6 (Bowman and Bailey 1998; Hincks and Mackie 1997). However, zebra mussel pH tolerance can vary between habitats because it is impacted by the presence of critical ions such as  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  (Table 1). The pH range for successful larval development to a settled juvenile in zebra mussels is estimated to be 7.4-9.4 (Sprung 1987). It is unknown but likely similar in quagga mussels. For this reason, a pH of  $\geq 7.4$  was considered the lower limit for both species in development of colonization risk assessments for the watersheds of the San Jacinto and lower Trinity Rivers.

### **3.4 Oxygen Requirements**

Zebra and quagga have generally similar tolerances of hypoxic conditions with incipient tolerated levels for adults considered to be  $>10\%$  of full air oxygen saturation (i.e., partial pressure  $\text{O}_2 = 2.13$  kPa) (Johnson and McMahon 1998, unpublished data). While unknown in quagga mussels, the lower oxygen concentration limit for development in zebra mussels to a settled juvenile is considered to be 32 percent of full air oxygen saturation (i.e., partial pressure  $\text{O}_2 = 4.3$  kPa) (Sprung 1987) (Table 1). Based on roughly equivalent lower  $\text{O}_2$  concentration limits for both species, an oxygen concentration of  $\geq 32$  percent full air oxygen saturation (i.e., partial pressure  $\text{O}_2 = 4.3$  kPa) was considered the requirement for larval development to a settled juvenile in both species for the purpose of this risk assessment. Because both species have a relatively low tolerance of hypoxia, they would be unlikely to penetrate hypoxic hypolimnetic waters below depths of 5-6 m in Lake Houston (Table 2).

## **4.0 Risk Assessment Methodology**

Water quality data was provided by AECOM for 11 stations located on the watersheds of the San Jacinto and lower Trinity Rivers and Lake Houston. Three stations were located on the San Jacinto River watershed above Lake Houston, five stations on the lower Trinity River watershed, and three stations were in Lake Houston. Station site identifications and locations are displayed on Figure 1 and are:

1. EC\_NEWPP, City of Houston's (COH) Intake for Northeast Water Purification Plant (NEWPP) near Lake Houston, San Jacinto River
2. EC\_CWALynch, Coastal Water Authority (CWA) Canal before Lynchburg Reservoir, San Jacinto River
3. EC\_WestFork, West Fork, San Jacinto River near Humble, TX (at US 59)
4. SWQM\_10896, Trinity River 125 m upstream of FM 787, near Romayor, Liberty Co., TX

5. EC\_CWATRPS, CWA Canal at Trinity River near Dayton, TX
6. EC\_CWAMid , CWA Canal at diversion to Cedar Point Lat. System, transferring water from the Trinity River to Lynchburg Reservoir
7. EC\_TrinCaper, Trinity River at Hwy 105 (5 miles upstream of Capers Ridge diversion point)
8. EC\_LuceBayou, Luce Bayou above Lake Houston near Huffman, TX
9. EC\_EastFork, Lake Houston west of Magnolia Point, East Fork San Jacinto River/Caney Creek Arm in Lake Houston
10. EC\_Lake Houston\_B1, Lake Houston near U.S. Geological Survey (USGS) 295554095093401 (Site B, inside solar bees)
11. EC\_Lake Houston\_B2, Lake Houston near USGS 295826095082200 (Site A, outside solar bees)

The main data set consisted of water quality data for all sample sites except Surface Water Quality Monitoring (SWQM) taken on 8/24, 9/9-14, 9/28, and 10/13 during 2010 (Table 2).

Additional data included continuously monitored water quality for the following:

- EC\_NEWPP from mid-2008 through mid-2010
- EC\_LuceBayou from 1990 through 1999, and 2000
- SWQM\_10896 from 1990 through 1999
- Lake Houston from 1990 through 2010.

Water quality data sets for all sampling stations were examined for the four factors most likely to impact successful establishment of zebra or quagga mussels including summer surface water temperatures, calcium concentration, surface water pH, and surface water dissolved oxygen concentration (Table 1).

Based on best available peer reviewed data on zebra and quagga mussel tolerance limits for these physical parameters (see section 2.0 above and Table 1), specific levels of each parameter were selected that represented the probability of a waterbody to host a sustainably reproducing mussel population. Three probability categories for establishment of sustainably reproducing zebra or quagga mussel populations were developed for each physical parameter. These were:

1. Low Probability: mussels are unlikely to establish a sustainably reproducing population
2. Moderate Probability: mussels may establish a population but stress resulting from a physical parameter(s) approaching tolerated limits may prevent massive colony development
3. High Probability: All examined physical water parameters fall with the limits for establishment of a thriving, sustainably reproducing mussel population capable of attaining high density.

The ranges of the four water quality parameters examined corresponding to these three risk probability levels are set out in Table 3.

## 5.0 Quagga Mussel Risk Assessment

The maximum incipient upper thermal limit of quagga mussels from the warm surface waters of Lake Mead (NV and AZ) has been estimated to be 28°C (Morse, 2009) which is similar to other estimates for this species (Spidle et al 1995) (Table 1). Quagga mussels appear to be able to survive and develop dense populations in the shallow surface waters of Lake Mead because ambient water temperatures rarely exceed their incipient upper thermal limit of 28°C, and if they do, only for very short durations rarely exceeding 30°C (Morse, 2009). Thus, quagga mussels in Lake Mead do not appear to be exposed to lethal temperatures for long enough to induce extensive mortality. In contrast, at all 11 sites examined in San Jacinto and lower Trinity Rivers and in Lake Houston, summer surface water temperatures appeared to exceed the 28°C incipient upper thermal limit of quagga mussels by  $\geq 2^\circ\text{C}$  (see station surface water temperatures for 8/24 and 9/14/2010 in Table 2). The lowest recorded surface water temperature among the examined stations was 30.1°C at EC\_NEWPP on 9/14/2010 (Table 2). Thus, long-term exposure to surface water temperatures greater than the 28°C incipient upper limit of quagga mussels would be highly likely to inhibit establishment of this species anywhere in the watersheds of the San Jacinto and lower Trinity Rivers. Therefore, an overall risk assessment of low probability for establishment of a sustainably reproducing population of quagga mussels was assigned to all 11 examined stations (Table 4). Continuous data sets for EC\_NEWPP, EC\_LuceBayou, SWQM\_10896, and Lake Houston also indicated that surface water temperatures remained above the 28°C incipient upper thermal limit of quagga mussels for extended periods during summer months. At stations EC\_Lake Houston\_B1 and EC\_Lake Houston\_B2 surface water temperatures on 8/24 and 9/14/2011 exceeded 29°C to depths of 4-5 m where waters became too hypoxic to support quagga mussels (Tables 1 and 2) suggesting that cooler hypolimnetic waters would be too hypoxic during summer months to provide quagga mussels a refuge from lethal summer epilimnetic water temperatures. In addition, at the EC\_LuceBayou and EC\_EastFork stations, mean calcium concentrations of 12.92 and 11.56 mg Ca/L (Table 4), were at levels low enough that moderate or low risks of quagga mussel establishment could be assigned, respectively. In contrast, all 11 stations had mean surface water O<sub>2</sub> concentrations and pH levels that exceeded those required for high probability of establishment of a quagga mussel population.

## 6.0 Zebra Mussel Risk Assessment

Unlike quagga mussels, the relatively higher incipient upper thermal limit of zebra mussels, particularly in warm southwestern waterbodies, of 32°C (Morse, 2009) prevented assignment of a low probability of establishment for the 11 examined stations based on water temperature regime alone (Table 4). Thus, the probability for establishment of a sustainably reproducing zebra mussel population is individually discussed for each station below.

### 6.1 EC\_NEWPP, COH Intake for NEWPP

The EC\_NEWPP station had an O<sub>2</sub> concentration range (34.7-75.5% of full air O<sub>2</sub> saturation), mean pH (8.0), mean calcium concentration (15.77 mg Ca/L), and summer surface water temperatures (31.1-31.4°C) (Table 2) that all fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. This assessment was supported by data recorded from mid-2008 to mid-2010 at the station which indicated that surface water temperature, pH and calcium concentration all

generally remained within limits to support assignment of a high probability for zebra mussel establishment.

## **6.2 *EC\_CWALynch, CWA Canal before Lynchburg Reservoir***

The EC\_CWALynch station had an O<sub>2</sub> concentration range (76.2-96.5% of full air O<sub>2</sub> saturation), mean pH (7.5), and mean calcium concentration (15.77 mg Ca/L) (Table 2) that fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. However, its relatively elevated surface water temperatures of 31.6-32.5°C fell within a range for moderate risk of zebra mussel population establishment (Table 2). Thus, this station was assigned a moderate risk for zebra mussel population establishment at low density levels in spite of having O<sub>2</sub> concentration, pH and calcium concentration regimes capable of supporting a sustainably reproducing population (Table 4). On the assumption that water enters the CWA canal from the Trinity River through an intake structure near the EC\_CWATRPS station, it is possible that if Lake Livingston became infested with zebra mussels that the mussel's planktonic larvae could be carried downstream in the Trinity River to be entrained in water transferred from EC\_CWATRPS intake through the CWA Canal to be released into the Lynchburg Reservoir at the EC\_CWALynch station. For that reason water quality parameters in Lake Lynchburg proper should be examined to estimate the likelihood that it could support a sustainably reproducing zebra mussel population.

## **6.3 *EC\_WestFork, West Fork San Jacinto River near Humble, TX (at US 59)***

The EC-WestFork station had an O<sub>2</sub> concentration range (64-6-117.0% of full air O<sub>2</sub> saturation), mean pH (8.1), mean calcium concentration (23.7 mg Ca/L) and summer surface water temperatures (31.0-32.0°C) (Table 2) that all fell within the limits to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. However, as this station appears to be located on the West Fork of the San Jacinto River and does not appear to have an impounded waterbody upstream of its location, it may not be suitable for development of a zebra mussel population as water flow would transport the mussel's planktonic mussel downstream before they could reach the settlement stage (i.e., 2-3 weeks).

## **6.4 *SWQM\_10896, Trinity River 125 m upstream of FM 787, near Romayor, Liberty Co., TX***

Based on data collected at the SWQM\_10896 station from 1990-1999, surface water O<sub>2</sub> concentration was generally >50%, pH ranged from 6.3 – 8.85, but was generally >7.0, calcium concentration ranged from 24-45 mg Ca/L, and summer surface water temperatures generally did not exceed 32°C. Thus, the range for all four parameters fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population.

## **6.5 *EC\_CWATRPS, CWA Canal near Dayton, TX***

The EC\_CWATRPS station had an O<sub>2</sub> concentration range (80.3-107.6% of full air O<sub>2</sub> saturation), mean pH (7.8), and mean calcium concentration (38.8 mg Ca/L) (Table 2) that fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a

large enough introduction of individuals occurred to initiate a population. However, its relatively elevated surface water temperatures of 31.7-32.7°C (Table 2) fell within the range for moderate risk of zebra mussel population establishment (Table 4). Thus, this station was assigned a moderate risk for zebra mussel population establishment at low density levels in spite of having O<sub>2</sub> concentration, pH and calcium concentration regimes capable of supporting a sustainably reproducing mussel population (Table 4). Lake Livingston lies upstream of station EC\_CWATRPS, if Lake Livingston became infested with a viable zebra mussel population, larvae could be hydrologically transported downstream from that site to settle in vicinity of the EC\_CWATRPS Station and/or be entrained at the station's intake to be transported through the CWA Canal to Lynchburg Reservoir.

#### **6.6 *EC\_CWAMid, CWA Canal at diversion to Cedar Point Lat. System***

The EC\_CWAMid station had an O<sub>2</sub> concentration range (65.6-76.4% of full air O<sub>2</sub> saturation), mean pH (7.5), and mean calcium concentration (38.7 mg Ca/L) (Table 2) that fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. However, its elevated surface water temperatures of 32.4-33.3°C (Table 2) fell outside the upper 32°C incipient upper thermal limit of zebra mussels allowing this site to be assigned a low risk probability for mussel population establishment (Table 4) in spite of having O<sub>2</sub> concentration, pH and calcium concentration regimes capable of supporting a sustainably reproducing population (Table 4). However, if Lake Livingston became infested with zebra mussels, planktonic mussel larvae transported down the Trinity River during cooler reproductive periods (12-24°C) could be carried through the CWA Canal, on which EC-CWAMid is situated, to infest Lynchburg Reservoir if the reservoir proves capable of sustaining a reproducing population.

#### **6.7 *EC\_TrinCaper, Trinity River at Hwy 105 (5 miles upstream of Capers Ridge diversion point)***

The EC\_TrinCaper station had an O<sub>2</sub> concentration range (84.3-108.5% of full air O<sub>2</sub> saturation), mean pH (8.2) and mean calcium concentration (35.68) (Table 2) that fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. However, its elevated summer surface water temperatures of 32.2-32.6°C (Table 2) fell outside the incipient upper thermal limit of zebra mussels at 32°C (Table 3). Thus, this station was assigned a low risk for zebra mussel population establishment in spite of having O<sub>2</sub> concentration, pH and calcium concentration regimes capable of supporting a sustainably reproducing mussel infestation (Table 4).

#### **6.8 *EC\_LuceBayou, Luce Bayou above Lake Houston near Huffman, TX***

The EC\_LuceBayou station had an O<sub>2</sub> concentration range (45.3-108.4% of full air O<sub>2</sub> saturation) and mean pH (7.9) (Table 2) that fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. However, its mean calcium concentration of 12.92 mg Ca/L and relatively elevated summer surface water temperatures of 31.4-32.6°C (Table 2) both fell within the range for moderate risk of zebra mussel population establishment (Table 4). Thus, the EC\_LuceBayou station was assigned a moderate risk for zebra mussel population establishment in spite of having O<sub>2</sub> concentration and pH regimes capable of supporting a sustainably reproducing population (Table 4).

**6.9     *EC\_EastFork, Lake Houston west of Magnolia Point, East Fork San Jacinto River/Caney Creek Arm in Houston, Texas***

The EC\_EastFork station had an O<sub>2</sub> concentration range (117.0-137.9% of full air O<sub>2</sub> saturation) and mean pH (8.8) (Table 2) that fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. However, its mean calcium concentration of 11.6 mg Ca/L and elevated summer surface water temperatures of 34.5-34.9°C (Table 2) both fell well outside the tolerated limits of zebra mussels at >12 mg Ca/L and <32°C (Table 3). Thus, this station was assigned a low risk for zebra mussel population establishment in spite of having O<sub>2</sub> concentration and pH regimes capable of supporting a sustainably reproducing population (Table 4).

**6.10    *EC\_Lake Houston\_B1, Lake Houston near USGS 295554095093401 (Site B, inside solar bees)***

Physical surface water data collection was limited to 8/24 and 9/14/2011 at the EC\_Lake Houston\_B1 station. Based on this relatively limited data set, surface water (depth 0.5 m) at the *EC\_Lake Houston\_B1* station had an O<sub>2</sub> concentration range (120.3-153.6% of full air O<sub>2</sub> saturation), mean pH (8.8), mean calcium concentration (14.0 mg Ca/L) and summer surface water temperatures (30.9-32.0°C) (Table 2) that all fell within the limits required to assign a high risk for establishment of a reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. While this risk assessment was based on only two sampling periods, a longer-term data set on surface water temperature, O<sub>2</sub> concentration and pH (1990-2010) provided by AECOM supported the high probability assessment.

**6.11    *EC\_Lake Houston\_B2, Lake Houston near USGS 295826095082200 (Site A, outside solar bees)***

Physical surface water data collection was limited to 8/24 and 9/14/2011 at the EC\_Lake Houston\_B2 station. Based on this relatively limited data set, the EC\_Lake Houston\_B2 station (depth = 0.5 m) had an O<sub>2</sub> concentration range (117.9-153.2% of full air O<sub>2</sub> saturation), mean pH (8.9), and summer surface water temperatures (30.9-32.1°C) (Table 2) that all fell within the limits required to assign a high risk for establishment of a sustainably reproducing zebra mussel population (Table 4) if a large enough introduction of individuals occurred to initiate a population. Calcium concentration data was not available for the EC\_Lake Houston\_B2 station so it was assumed to be similar to that for the EC\_Lake Houston\_B1 station at 14.0 mg Ca/L. While this risk assessment was based on only two sampling periods, a longer-term data set on surface water temperature, O<sub>2</sub> concentration and pH (1990-2010) provided by AECOM supported the high probability assessment.

## 7.0 Discussion, Conclusions and Recommendations

Based on an analysis of water quality data provided by AECOM, nine of the eleven stations of interest appeared to have either a moderate (i.e., EC\_CWALynch, EC\_CWAMid, EC\_CWATRPS, and EC\_LuceBayou) or high probabilities (i.e., EC\_WestFork, EC\_NEWPP, EC\_Lake Houston\_B1, EC\_Lake Houston\_B2 and SWQM\_10896) to support a sustainably reproducing zebra mussel population. Only the EC\_Trincaper and EC\_WestFork Stations appeared to have a low probability of supporting a sustainably reproducing zebra mussel population based primarily on mid-summer water temperatures exceeding the zebra mussel's incipient upper thermal limit of 32°C (Table 4). In contrast, none of the stations appeared to be able to support sustainably reproducing populations of quagga mussels primarily because their mid-summer water temperatures exceeded this species' incipient upper thermal limit of 28°C (Table 4). Thus, while the examined waterbodies, rivers and canals appear to be resistant to quagga mussel invasion, most of them with the possible exception of the East Fork/Caney Creek arms of the San Jacinto River Drainage (Figure 1, Table 4), appear capable of supporting zebra mussels.

Zebra mussels were first discovered in Texas on the south shore of the lower end of Lake Texoma on April 3, 2009 (Texas Parks and Wildlife Department, 2009). By the fall of 2011, a dense population of zebra mussels, often in excess of 50,000 individuals, had developed on hard surfaces on the north and south shores of the lower half of the lake (McMahon, personal observations). Soon after zebra mussels were discovered in Lake Texoma, the North Texas Municipal Water District (NTMWD) voluntarily shut down a pipeline that transferred water from Lake Texoma on the Red River Drainage to Lake Lavon on the East Fork of the Trinity River where its main water treatment facility was located (U.S. Army Corps of Engineers, Fort Worth District, 2011). The pipeline presently remains shutdown in order to prevent infestation of Lake Lavon with zebra mussels as a result of settlement of larvae entrained on water transfers from Lake Texoma. Since 25 percent of NTMWD water supplies come from Lake Texoma, the continued shutdown of the Texoma conduit has caused severe water shortages in the municipalities that it serves and an unprecedented drawdown of Lake Lavon during the summer of 2011 (North Texas Municipal Water District 2011a, 2011b). Zebra mussel infestation has also been associated with a massive cyanobacteria bloom in Lake Texoma during the summer of 2011 (U.S. Army Corps of Engineers, Tulsa District 2011). Adult zebra mussels can also be transferred between isolated waterbodies attached to the hulls of boats and on previously submerged material and equipment (Claudi and Mackie 1994). During 2011, boats previously moored in Lake Texoma with adult zebra mussels attached to their hulls were transferred to and found moored at marinas on Lake Lavon and Lake Ray Hubbard, which is also on the East Fork of the Trinity River, suggesting that movement of recreational boats from Lake Texoma could eventually lead to the establishment of zebra mussels in reservoirs on the upper Trinity River Basin.

Quagga mussels were first observed in the Boulder Basin of Lake Mead (Nevada /Arizona) in 2007. Their larvae were rapidly transported downstream to infest Lakes Mohave and Havasu (McMahon, 2011). Similarly, establishment of zebra mussels in waterbodies on the upper Trinity River watershed could rapidly lead to mussel infestation of downstream waterbodies, such as Lake Livingston. Soon after the initial establishment of quagga mussels in the lower Colorado River, movement of larvae via interbasin water transfers from Lakes Mead and Mohave led to the establishment of sustainable infestations in a number of reservoirs in southern California and central Arizona (U.S. Geological Survey 2011).

Similarly, if a zebra mussel population became established in Lake Livingston due to downstream hydrological transport of planktonic larvae from an infested reservoir(s) on the upper Trinity River watershed or by overland transport on recreational boats or other material or equipment previously moored or submerged in a mussel-infested waterbody such as Lake Texoma, larvae being carried downstream in the lower Trinity River could be transported to Lake Houston via the proposed water diversion system from the lower Trinity River to EC\_Luce Bayou for release into Lake Houston (Figure 1). While waters at EC\_LuceBayou were considered too warm during mid-summer to support a zebra mussel population (Table 4), mussel spawning leading to the presence of larvae in the water column would occur at cooler temperatures (12-24°C, Table 1) allowing their transport through a water diversion system to Luce Bayou into Lake Houston whose surface water temperature, pH, calcium concentration and oxygen concentration regimes indicate a high probability for supporting a sustainably reproducing mussel population (Table 4). Similarly, establishment of a zebra mussel population in Lake Conroe upstream of Lake Houston on the West fork of the San Jacinto River could also lead to infestation of Lake Houston (Figure 1). Larval transport from the Trinity River through the CWA Canal could also lead to zebra mussel infestation of Lynchburg Reservoir which was assessed to have a moderate probability of supporting a sustainably reproducing mussel population at the EC\_CWALynch outfall. Indeed, transport of larvae on water transfers from zebra mussel infested waterbodies could potentially lead to establishment of new populations in isolated, previously uninfested waterbodies capable of supporting mussel populations. For these reasons, the water quality of Lakes Livingston, and Conroe and Lynchburg Reservoir should also be assessed for their capacity to support sustainably reproducing zebra mussel populations.

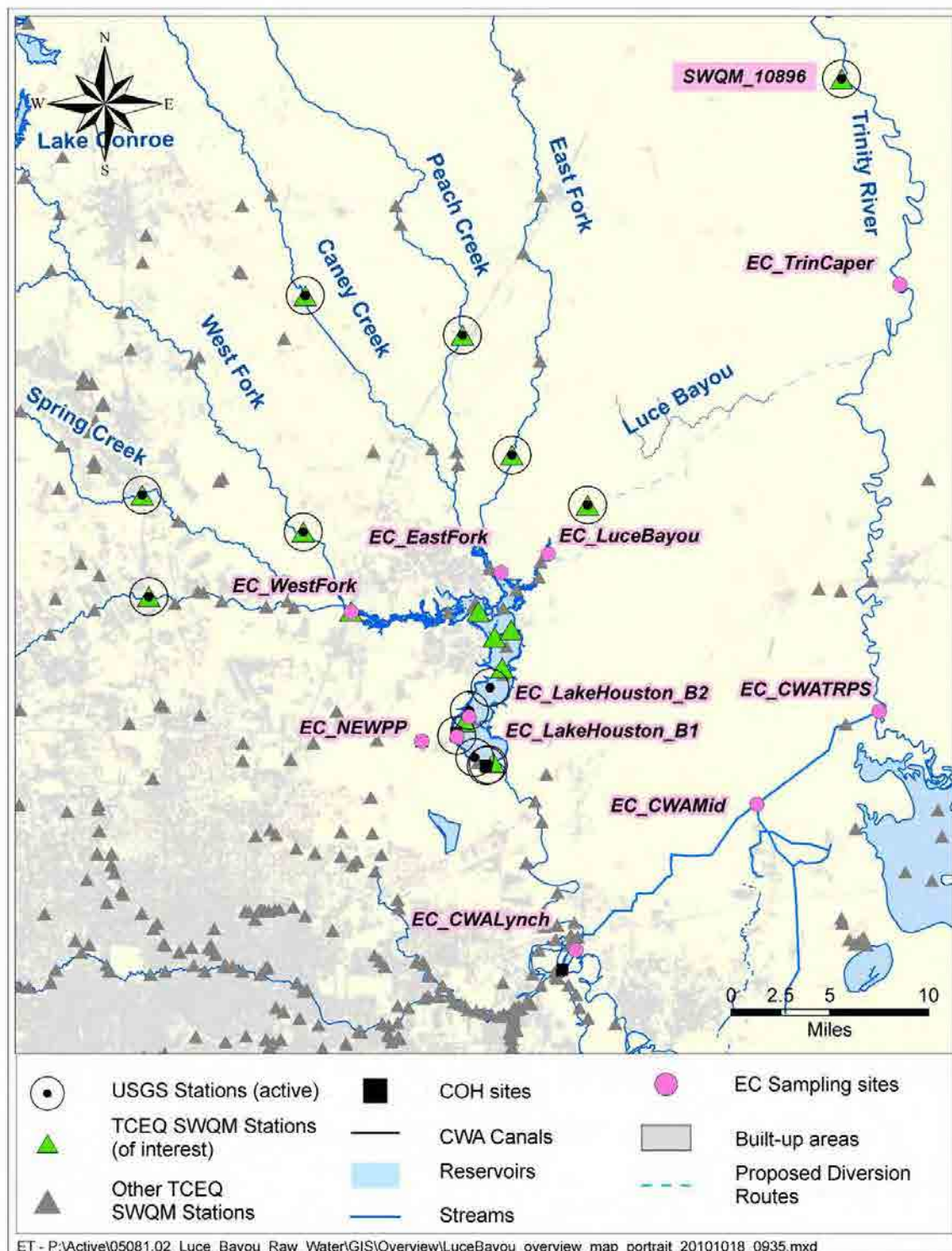
Overall this risk assessment suggests that the waterways and reservoirs on the watersheds of the San Jacinto and lower Trinity Rivers encompassed by the examined stations would be highly resistant to quagga mussel invasion due to their summer surface water temperatures being elevated above its incipient upper thermal limit of 28°C (Figure 1, Table 4). In contrast, zebra mussels with a higher incipient thermal limit of 32°C could become established in many of the waterways and waterbodies encompassed by the examined stations (Figure 1, Table 4). For this reason it may be important to initiate a monitoring system at these and other relevant stations, including Lakes Conroe, Livingston, and Houston, for the presence of zebra mussel larvae via examination of plankton net samples taken during peak spawning periods when surface water temperatures are 18-24°C. Samples can be examined for the presence of mussel veliger larvae with cross-polarized light microscopy (Johnson, 1995), flow-cell cytometry and/or PCR (Polymerase Chain Reaction) molecular analysis (Hosler, 2011). If detected, transfers of water containing mussel larvae can be halted in order to avoid mussel introduction to uninfested receiving waterbodies. Presence of a reproducing mussel population can also be detected by deployment and periodic examination of juvenile settlement monitors during the spring and fall when water temperatures are most suitable for reproduction and settlement at 18-24°C (McMahon 1996). In addition, hard surfaces can be periodically examined by Scuba divers for the presence of adult mussels (Claudi and Mackie 1994).

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**Figure 1.** Map of sampling stations (highlighted in pink) for which water quality data was examined for the potential for zebra or quagga mussels to develop sustainably reproducing populations (from Espey Consultants, Inc. 2011).

Risk Analyses for Establishment of Dreissenid Mussels at Selected Stations  
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**Table 1.** Comparison of resistance adaptations to physical factors of zebra (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis bugensis*).

Physical Factor	Zebra Mussels	Quagga Mussels	Comment	References
Incipient Upper Thermal Limit	29-32°C in N. America	28°C in N. America	Can vary based on individual size and nutritional condition, prior temperature experience and season of the year. Thermal tolerance appears subject to selection by elevated temperatures. Likely to be greater for populations at lower latitudes and in waterbodies receiving thermal effluents.	Elderkin and Klerks 2005 Hernandez 1995 Iwanyzki and McCauley 1993 Karateyev et al 1998 Morse 2009 Spidle et al. 1995
Incipient Lower Thermal Limit	0°C	0°C	Temperate species which survive over winter in iced over waterbodies in the northern portions of their range.	Karateyev et al 1998 McMahon 1996 McMahon et al 1995
Spawning Temperature	12°-24°C	9°-24°C	Spawning is maximized in <i>D. polymorpha</i> ≥18°-20°C which is also likely to be the case in <i>D. r. bugensis</i>	Claxton and Mackie 1998 Karateyev et al 1998
Temperature for Larval Development	12-24°C	unknown	The lower limit may be reduced for <i>D. r. bugensis</i> but requires experimental confirmation.	Claxton and Mackie 1998 Sprung 1987
Calcium	<8-12 mg Ca <sup>2+</sup> /L	<12 mg Ca <sup>2+</sup> /L	Based primarily on presence absence data in the St. Lawrence River	Hincks and Mackie 1997 Mellina and Rasmussen 1994 Jones and Ricciardi 2005
pH	Range = 6.0 to 8.5-9.6 pH 7.4-9.4 for larval development	Unknown	Ca <sup>2+</sup> and other ion concentrations may impact the tolerated pH range.	Bowman and Bailey 1998 Hincks and Mackie 1997 Sprung 1987
Low Oxygen Tolerance as % of full air O <sub>2</sub> Saturation	Po <sub>2</sub> >10.0% Po <sub>2</sub> > 32.3% for larval development Byssogenesis inhibited at ≤10%	Po <sub>2</sub> >10%	Appears to be temperature dependent – tolerance increases at lower temperatures. Likely to be greater in <i>D. polymorpha</i> .	Johnson and McMahon 1998 Matthews and McMahon 1999 McMahon and Johnson unpublished

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**Table 2.** Summary of sampling data for water temperature (°C), calcium concentration (mg Ca/L) , pH, and oxygen concentration (mg O<sub>2</sub>/L) at selected sites from the watersheds of the San Jacinto and lower Trinity Rivers and Lake Houston.

Site Code and Location	Date of Sample	Depth (m)	Temperature °C	mg Ca/L	pH	mg O <sub>2</sub> /L
<b>EC_WestFork</b>	8/24/2010	0.30	31.0	24.99	7.50	4.80
West Fork San Jacinto River near Humble, TX (at US 59)	9/14-15/2010	0.10	32.0	15.90	8.20	8.40
	9/20/2010	0.10	27.5	23.30	8.20	8.60
	10/13/2020	0.10	24.8	30.45	8.50	9.70
<b>Mean Values</b>		<b>0.15</b>	<b>28.8</b>	<b>23.66</b>	<b>8.10</b>	<b>7.88</b>
<b>EC_NEWPP</b>	8/24/2010	4.88	31.4	16.20	7.80	2.56
COH Intake for NEWPP	9/14/2010	4.88	30.1	14.49	7.60	5.70
	9/28/2010	4.88	27.4	15.80	8.00	5.50
	10/4/2010	4.88	25.5	16.59	8.60	4.90
<b>Mean Values</b>		<b>4.88</b>	<b>28.6</b>	<b>15.77</b>	<b>8.00</b>	<b>4.67</b>
<b>EC_CWALynch</b>	8/24/2010	0.25	32.5	40.43	7.20	6.70
CWA Canal before Lynchburg Reservoir	9/14/2010	0.10	31.6	33.61	7.70	5.60
	9/28/2010	0.10	27.2	34.90	7.70	7.20
	10/13/2010	0.10	24.9	42.40	7.50	6.70
<b>Mean Values</b>		<b>0.14</b>	<b>29.1</b>	<b>37.84</b>	<b>7.53</b>	<b>6.55</b>
<b>EC_CWAMid</b>	8/24/2010	0.10	33.3	41.14	7.30	4.90
CWA Canal at diversion to Cedar Point Lat. System	9/14/2010	0.10	32.4	33.99	7.60	5.10
	9/28/2010	0.10	27.8	34.90	7.70	6.00
	10/13/2010	0.10	25.2	44.72	7.50	5.40
<b>Mean Values</b>		<b>0.10</b>	<b>29.7</b>	<b>38.69</b>	<b>7.53</b>	<b>5.35</b>
<b>EC_CWATRPS</b>	8/24/2010	0.30	32.7	41.01	7.30	5.80
CWA Canal near Dayton, TX	9/14/2010	0.10	31.7	34.19	7.80	5.60
	9/28/2010	0.10	26.2	36.60	8.50	8.70
	10/13/2010	0.10	25.3	43.71	7.70	6.80
<b>Mean Values</b>		<b>0.15</b>	<b>29.0</b>	<b>38.88</b>	<b>7.83</b>	<b>6.73</b>
<b>EC_TrinCaper</b>	8/24/2010	0.35	32.6	37.68	8.10	6.10
Trinity River at Hwy 105 (5 miles upstream of Caper's Ridge diversion point)	9/14/2010	0.10	32.2	32.76	8.50	7.90
	9/28/2011	0.10	29.3	36.60	8.60	8.20
	10/13/2010	0.10	27.2	43.31	7.70	7.60
<b>Mean Values</b>		<b>0.16</b>	<b>30.3</b>	<b>35.68</b>	<b>8.23</b>	<b>7.45</b>
<b>EC_LuceBayou</b>	8/24/2010	0.10	32.6	13.07	8.20	8.10
Luce Bayou above Lake Houston near Huffman, TX	9/14/2010	0.10	31.4	11.74	8.90	8.00
	9/28/2010	0.10	27.2	13.20	6.80	3.60
	10/13/2010	0.10	24.9	13.66	7.80	8.20

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**Table 2. Continued**

Site Code and Location	Date of Sample	Depth (m)	Temperature °C	mg Ca/L	pH	mg O <sub>2</sub> /L
<b>EC_EastFork</b>	8/24/2010	0.30	34.5	12.76	8.30	8.20
Lake Houston west of	9/14/2010	0.30	34.9	9.25	8.60	9.60
Magnolia Point, East Fork	9/28/2010	0.10	29.8	11.80	8.50	9.30
San Jacinto River/ Caney	10/13/2011	0.10	26.6	12.43	8.50	9.60
Creek Arm in Houston						
<b>Mean Values</b>		<b>0.20</b>	<b>31.5</b>	<b>11.56</b>	<b>8.48</b>	<b>9.18</b>
<b>EC_Lake Houston_B1</b>	8/24/2010	0.00	32.1		7.90	9.30
Lake Houston near		0.50	32.0		8.00	9.16
USGS_295554095093401		1.00	31.9		8.14	8.80
(Site B, inside solar bees)		2.00	31.8		8.14	8.40
		3.00	31.8		8.12	8.60
		4.00	31.3		8.00	6.10
		5.00	31.0		7.70	4.30
		6.00	30.6		7.60	1.50
		7.00	30.2		7.20	1.60
	9/14/2010	0.00	30.9	13.98	9.50	11.40
		0.50	30.9		9.50	11.40
		1.00	30.7		9.40	10.70
		2.00	30.5		9.30	9.70
		3.00	30.5		9.30	9.20
		4.00	29.7		8.20	3.90
		5.00	28.9		7.70	0.20
		6.00	28.6		7.00	0.00
<b>Mean Values (Depth 0.5)</b>		<b>0.50</b>	<b>31.5</b>	<b>13.98</b>	<b>8.75</b>	<b>10.28</b>
<b>EC_Lake Houston_B2</b>	8/24/210	0.00	32.3		8.10	9.10
Lake Houston near		0.50	32.1		8.20	8.60
USGS_295826095082200		1.00	31.8		8.20	8.30
(Site A, outside solar bees)		2.00	31.2		7.80	4.00
		3.00	31.1		7.70	3.30
		4.50	31.0		7.50	2.00
	9/14/2020	0.00	31.3		9.50	11.80
		0.50	30.9		9.50	11.40
		1.00	30.7		9.40	10.80
		2.00	30.4		9.40	10.30
		3.00	30.3		9.30	9.20
		4.00	29.4		8.30	4.00
		4.30	29.1		7.70	1.50
<b>Mean Values (Depth 0.5)</b>			<b>31.5</b>	<b>---</b>	<b>8.85</b>	<b>10.00</b>

**Table 3.** Comparison of the probability for successful invasion of waterbodies based on key physical parameters and resistance adaptations to physical factors for zebra (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis bugensis*) (See Table 1 for toleration of key physical parameters in dreissenid mussels).

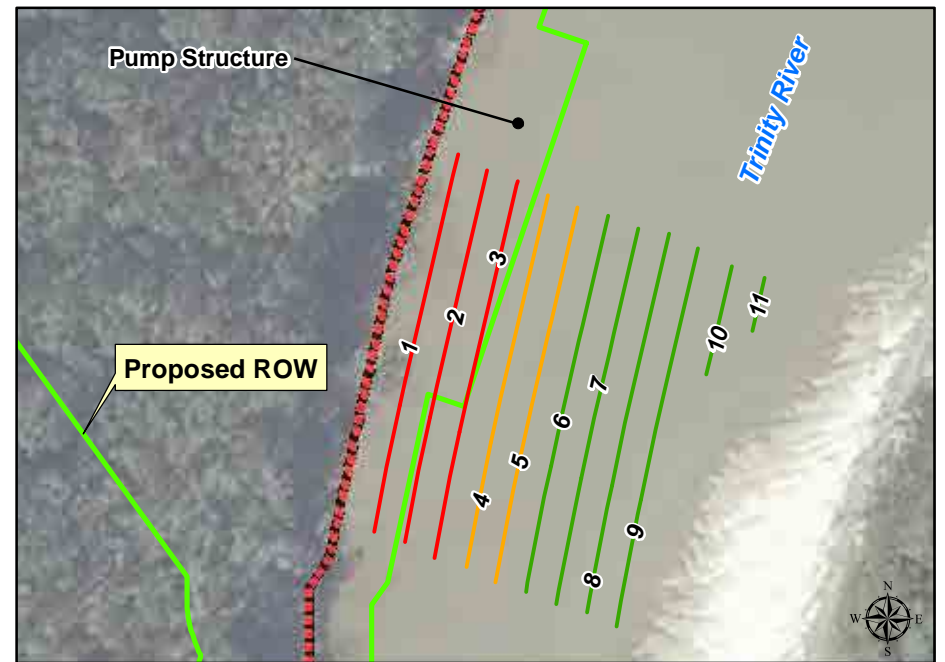
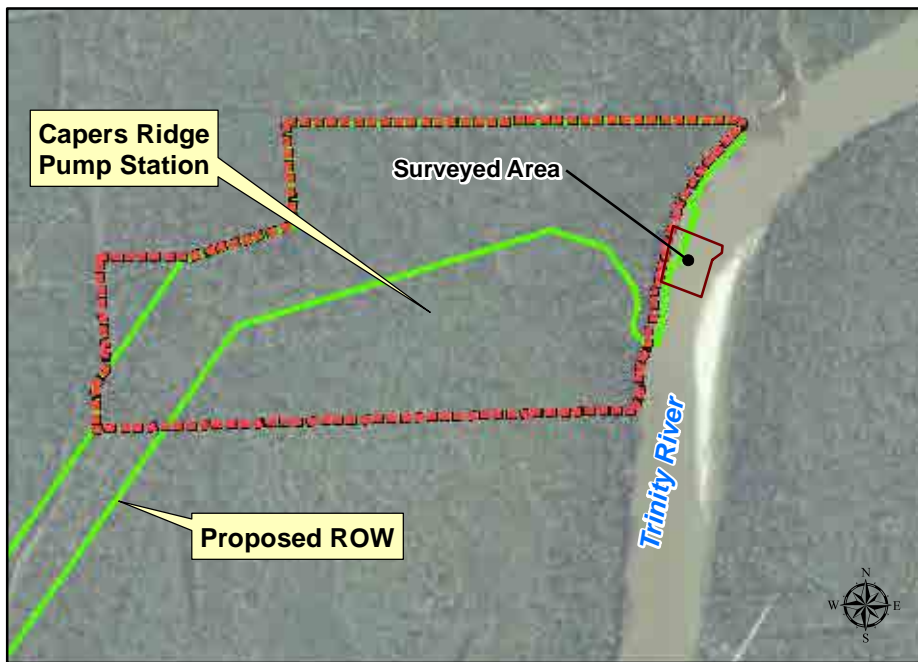
Physical Factor	Species	Probability of Successful Colonization		
		Low Probability	Moderate Probability	High Probability
Maximum 30-day average summer surface water temperature	Zebra Mussel	>32°C	30-32°C	<30°C
	Quagga Mussel	>28°C	27-28°C	<27°C
Average surface water calcium concentration	Zebra Mussel	<12 mg/L	12-14 mg/L	>14 mg/L
	Quagga Mussel	Calcium Concentration Limits Unknown		
Average surface water pH	Zebra Mussel	<7.0	7.0-7.4	>7.4
	Quagga Mussel	pH Limits Unknown		
Average low oxygen concentration (% of full air O2 Saturation)	Zebra Mussel	<10%	10-25%	>25%
	Quagga Mussel	<10%	10-30%	>30%

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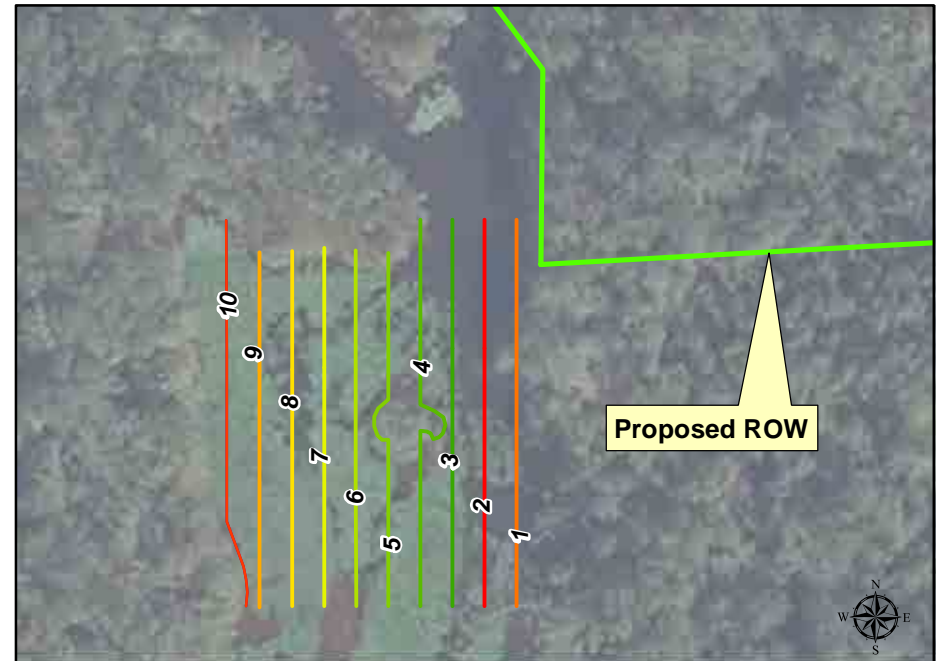
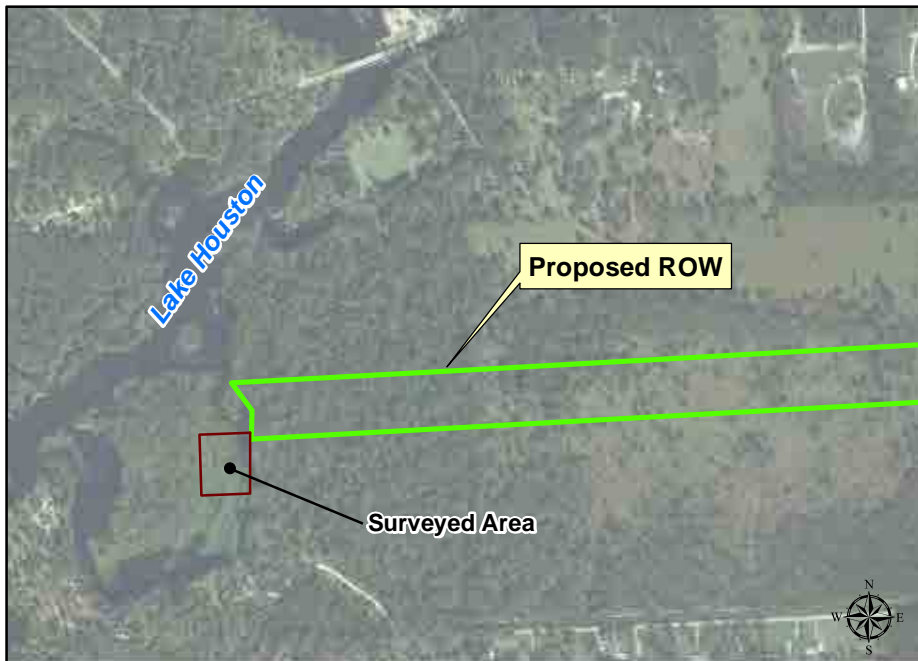
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**Table 4.** Risk probabilities for dreissenid mussels to invade and develop sustainably reproducing populations at selected sites in the watersheds of the San Jacinto and Lower Trinity Rivers and Lake Houston. Key: + = high probability, 0 = moderate probability, - = low probability. Assessments not in parentheses are for zebra mussels while those within parenthesis are for quagga mussels.

Site and Location	O <sub>2</sub> Concentrati on % Air saturation	pH Mean	Ca Mean mg/L	Temperature Summer Surface Water 8/24 and 9/14/2011	Risk Level
<b>EC_NEWPP</b> , COH Intake for NEWPP	34.7-75.5% + (+)	8.0 + (+)	15.77 + (+)	30.1-31.4°C + (-)	+ (-)
<b>EC_CWALynch</b> , CWA Canal before Lynchburg Reservoir	76.2-92.5% + (+)	7.5 + (+)	37.8 + (+)	31.6-32.5°C 0 (-)	0 (-)
<b>EC_WestFork</b> , West Fork San Jacinto River near Humble, TX (at US 59)	64.6-117.0% + (+)	8.1 + (+)	23.7 + (+)	31-32°C + (-)	+ (-)
<b>SWQM_10896</b> , Trinity River 125 meters upstream of FM 787, near Romayor, Liberty Co., TX	≥50% + (+)	7.6-8.1 + (+)	28-45 + (+)	≤32°C during summer + (-)	+ (-)
<b>EC_CWATRPS</b> , CWA Canal near Dayton, TX	80.3-107.6% + (+)	7.8 + (+)	38.8 + (+)	31.7-32.7 0 (-)	0 (-)
<b>EC_CWAMid</b> , CWA Canal at diversion to Cedar Point Lat. System	65.6-76.4% + (+)	7.5 + (+)	38.7 + (+)	32.4-33.3°C - (-)	- (-)
<b>EC_TrinCaper</b> , Trinity River at Hwy 105 (5 miles upstream of Capers Ridge diversion point)	84.3-108.5% + (+)	8.2 + (+)	35.68 + (+)	32.2-32.6 - (-)	- (-)
<b>EC_LuceBayou</b> , Luce Bayou above Lake Houston near Huffman, TX	45.3-108.4% + (+)	7.9 + (+)	12.92 0 (0)	31.4-32.6°C 0 (-)	0 (-)
<b>EC_EastFork</b> , Lake Houston west of Magnolia Point, East Fork San Jacinto River/Caney Creek Arm in Houston	117.0- 137.9% + (+)	8.8 + (+)	11.56 - (-)	34.5-34.9°C - (-)	- (-)
<b>EC_Lake Houston_B1</b> , Lake Houston near USGS 295554095093401 (Site B, inside solar bees) depth = 0.5 m	120.3- 153.6% + (+)	8.8 + (+)	14.0 + (+)	30.9-32.0°C + (-)	+ (-)
<b>EC_Lake Houston_B2</b> , Lake Houston near USGS 295826095082200 (Site A, outside solar bees) depth=0.5 m	117.9- 153.2% + (+)	8.9 + (+)	Not Available	30.9-32.1°C + (-)	+ (-)



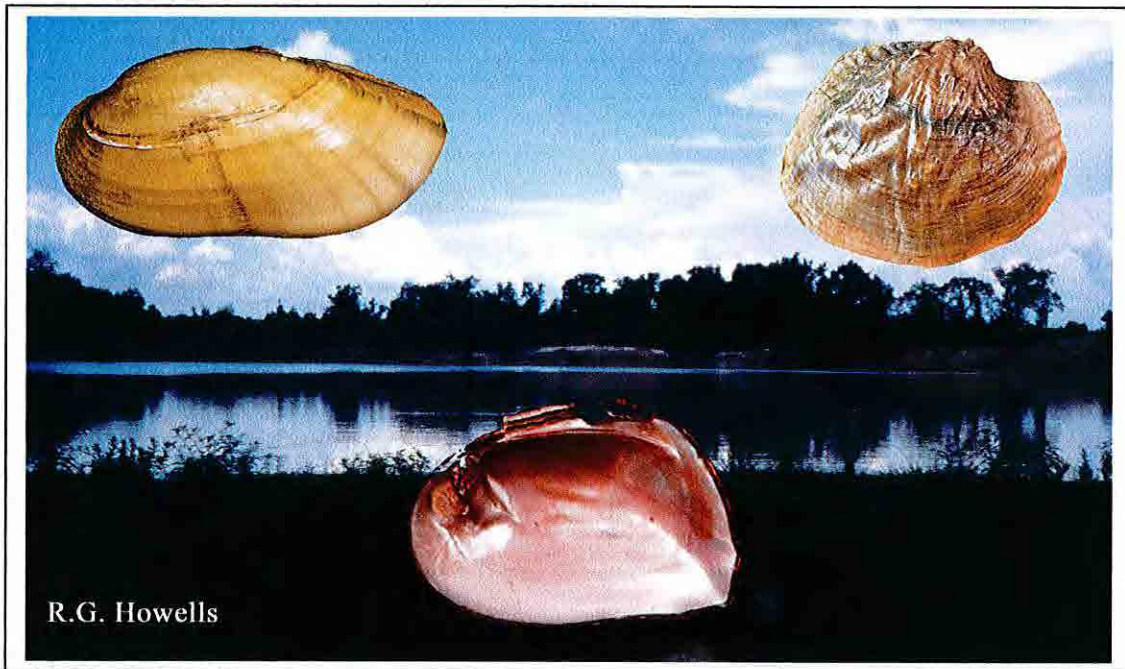
**Capers Ridge Pump Station**



**Lake Houston Discharge Structure**

**Exhibit 1 - Intake and Discharge Mussel Survey Locations**

**FRESHWATER MUSSELS OF THE LOWER  
TRINITY AND SAN JACINTO RIVERS, TEXAS:  
ASSOCIATIONS WITH THE LUCE BAYOU  
INTERBASIN TRANSFER PROJECT**



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## ABSTRACT

Freshwater mussels (Family Unionidae) are important elements of aquatic ecosystems and key barometers of environmental quality because they are extremely sensitive to ecological change and degradation. Historically unionid mussels were fished commercially for shells to produce mother-of-pearl buttons and implant nuclei for cultured pearls, as well as for their own natural pearls. Most current importance reflects their precipitous decline in abundance with associated concerns for their continued survival. Numerous construction and habitat modification projects must now assess potential impacts on area freshwater mussels, particularly for those very rare species and taxa with very limited geographical distributions and small surviving populations. Surveys of freshwater mussels conducted in Texas, particularly in recent decades, indicate relative limited abundance and diversity is present in the lower Trinity River downstream of Lake Livingston and some areas of the San Jacinto River drainage. Further, mussels surviving in the lower Trinity River and Lake Houston are not presently known to include any rare unionid species currently being considered for state or federal listing. The Luce Bayou Interbasin Transfer Project is designed to relocate water from the lower Trinity River to the East Fork San Jacinto River just upstream of Lake Houston. This project would not appear to have any direct impact on mussel species that are candidates for state or federal listing or to pose any major threat to existing unionid populations. However, in mid-2009, invasive zebra mussel (*Dreissena polymorpha*) was found to have invaded Lake Texoma in the Red River drainage and the Lake Lavon area in the upper Trinity River system. In time, this harmful exotic bivalve may move down the Trinity River to invade lower stretches of that system. The Luce Bayou Project could then provide a path for invasion of the San Jacinto basin with subsequent potential impacts on native mussels and the aquatic ecosystem in general, as well as recreational, industrial, and urban water-use.

## ABOUT THE AUTHOR

Robert G. Howells is a fisheries research biologist. Professional history includes time on the staff of the Cleveland Museum of Natural History, Ohio, and 10 years with Ichthyological Associates, Inc. (IA), an environmental consulting firm working in the Middle Atlantic States. Studies at IA involved environmental impact assessments at oil refineries and fossil and nuclear fuel generating stations, including impingement and entrainment studies and research on micro- and macro-zooplankton, ichthyoplankton, and fin fishes in freshwater, marine, and estuarine environments. From 1984 through 2006, his work at Texas Parks and Wildlife Department's (TPWD) Heart of the Hill Fisheries Science Center, Ingram, Texas, centered on various sport fisheries issues, with special focus on freshwater mussels, exotic species, and aquatic macrophytes in Texas waters. Associated publications have included books on freshwater mussels and prohibited exotic fishes, shellfishes, and aquatic plants in Texas, as well as journal articles, symposia proceedings, technical reports, and an array of educational and informational materials. Following retirement from TPWD in mid-2006, his research, lecture, and writings on freshwater mussels, exotic species, and macrophytes have continued. His ongoing work includes development of a database of freshwater mussel records for Texas and creation of a new and updated book on the freshwater mussels in Texas.

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**August 2009**



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## INTRODUCTION TO FRESHWATER MUSSELS

Much of the following general discussion originated from Freshwater Mussels of Texas (Howells et al. 1996), with input from other recent publications including Cummings and Mayer (1992), Vidrine (1993), Watters (1993), Fichtel and Smith (1995), Strayer and Jirka (1997), Parmalee and Bogan (1998), Brim Box and Williams (2000), Cicerello and Schuster (2003), Sietman (2003), and Williams et al. (2008). Specific point by point citations have generally been eliminated in these introductory paragraphs due to the "general knowledge" nature of this information.

### Classification and Terminology

Unfortunately, terms like "mussel" and "clam" apply to a wide range of related and unrelated bivalve mollusks. Neither term is particularly specific. True marine mussels (Family Mytilidae) have species that can be found in brackish and even fresh waters and "clams" include several bivalve families that have members in marine and estuarine environments. In fresh water in North America, freshwater mussels or pearly mussels include two families (Unionidae and Margaritiferidae, with only the former found in Texas). However, native fingernail clams (Family Sphaeriidae) also occur in fresh water as do introduced exotic Asian clams (Family Corbiculidae). Zebra mussels (Family Dreissenidae) include two exotic species introduced in the U.S. and two native species (typically in coastal waters). Atlantic rangia (*Rangia cuneata*; Family Mactridae) may also occur in low-salinity waters in coastal areas. Other bivalve families occur in fresh waters elsewhere in the world.

There are approximately 300 species of freshwater mussels in North America (Williams et al. 1993), with over 50 species reported from Texas (Howells et al. 1996). Among these, 33-34 have been listed from the Trinity River basin and 28-29 have been reported in the San Jacinto River system of eastern Texas (Tables 1 and 2). Freshwater mussels are often extremely variable in morphology. Some species have particularly distinct ecophenotypes, forms of the same species that appear very different in different environments. This variety of forms of different species and similarity of some distinct species produced a confusing array of names and descriptions from the earliest scientific descriptions through the present. The recent development of biochemical genetic analysis has clarified some classification problems, but created others. The taxonomic status (species validity) of some freshwater mussels in Texas still remains to be resolved (Howells 2004a).

### Anatomy

As their name (bivalve) implies, freshwater mussel shells are made of two valves (a valve is one half of the shell) connected by a ligament along the hinge line. Shells are primarily calcium carbonate in layers of aragonite and calcite, with three major shell layers including the periostracum or epidermis (exterior), prismatic middle layer, and nacre or mother-of-pearl that lines the interior of the shell. This inner layer is often completely or partially iridescent (only freshwater mussels and marine pearl oysters among bivalves have this iridescence). The interior of the shell (mantle cavity) is lined by soft tissue called the mantle that secretes the shell itself. Major soft tissue anatomy includes a muscular foot that extends forward out the anterior end to dig into the substrate, other muscles (adductor muscles to close the valves, retractor muscles to withdraw the foot, etc.), two gills on each side of the body, and an incurrent aperture to bring water containing food and oxygen into the mantle cavity and an excurrent aperture to discharge this water, waste (feces), and uneaten items (pseudofeces). Gills are used to filter food items from water as it passes through the mantle cavity. Freshwater mussels have a digestive tract with a mouth, stomach, intestine, palps (to pass food from the gills to the mouth), and anus, as well as a circulatory system with a heart, but lack a definite brain.

### Basic Biology and Life History

Unlike marine mussels and zebra mussels that attach to solid objects with adhesive byssal threads, freshwater mussels dig into the substrate. Some, perhaps all, unionid species may possess adhesive byssal threads for brief periods immediately after transformation to the juvenile stage and commencement of life in the substrate. However, as older juveniles and adults, all burrow into the substrate. Most species dig into the sediment on an angle with the anterior end and foot down and the posterior end and apertures upward. Often 70-95% of the animal is positioned

below the surface, with only a limited amount of shell exposed. Some species bury completely and must draw water carrying oxygen and food through the gravel bed in which they live; only a few may lay horizontally on the substrate surface (under normal conditions).

### Feeding

Freshwater mussel juveniles and adults are filter feeders. They remove algae, bacteria, protozoans, organic particles and perhaps dissolved organic chemicals from the water column. Very recently transformed juveniles may use their foot to obtain tiny particles prior to the development of filter-feeding organs. Unwanted particles removed from the water are coated in mucus and ejected as pseudofeces.

### Reproduction

The reproductive cycle in freshwater mussels is both complex and unique. Most species have distinct sexes, though a few may be hermaphrodites. In some species, sexes may be strongly dimorphic with males and females being slightly to very different in appearance. Generally, males release sperm into the water column. During feeding and respiration, females bring this in through their incurrent apertures. Fertilized eggs and developing larvae are held in marsupial pouches on their gills. Larval mussels, called glochidia, are parasites on fishes (one species not found in Texas uses a salamander). Female mussels typically release developed glochidia into the water column individually or in groups called conglomerates (some of which resemble worms, insects, or larval fishes). Some female mussels develop mantle flaps or lures that resemble minnows (*Lampsilis*), worms (*Toxolasma*), or insects (*Ligumia*) that are extended and wiggled to lure potential hosts closer and increase chances of released glochidia reaching the needed host. Unionids are often grouped as short-term or long-term brooders reflecting how long females may carry glochidia and during how much of the year females may be gravid.

Glochidia do not swim, but drift with the current or rely on the host fish attempting to consume them. Released glochidia have a limited period of time (usually hours) to find the appropriate species of host fish and attach to the correct location on the host (typically either gills or fins). Glochidia with spine-like hooks typically attach to fins, but those that are axe-head shaped or hookless usually need to attach to gills. Further, fishes that have been previously infected with mussel glochidia may develop an immunity to reinfection, particularly after several earlier infections. Therefore, any glochidia that fail to find the needed host fish, attach to the wrong species of fish, attach to the wrong place on the fish, or attach to fish with acquired immunity will die. Glochidia are true parasites and do obtain nutrient from their hosts. However, few fish in any population are usually infected at any point in time and those that are often carry only a few glochidia. Except in unusual cases, little or no harm comes to host fishes from their utilization by mussel glochidia.

Some mussels use a wide range of fish host species, but others are only known to use a single species. Giant floater (*Pyganodon grandis*) and washboard (*Megalania nervosa*) are each known to employ over 20 fish species. Bleuffer (*Potamilus purpuratus*) is only known to use freshwater drum (*Aplodinotus grunniens*) and cannot successfully complete its reproductive cycle unless that fish is available.

Encysted glochidia may remain on hosts for less than two weeks to several months depending on mussel and fish species and time of year. Upon development to the juvenile stage, recently transformed mussels drop from the host to begin life on the bottom. Young mussels that fall on unacceptable type substrates will die. Because most freshwater mussel distributional changes rely on host fishes for transport, mussels can be particularly abundant in areas frequented by host fishes.

The complex nature of unionid reproductive biology means that management of a freshwater mussel species also requires concurrent management of the needed fish host and appropriate habitats for both, including the various life stages of both fishes and mussels.

### Age and Growth

Freshwater mussels may live less than 10 years, but many species live 30 to 50 years, with several that exceed 100 years of age. Growth is most rapid during the first few years of life, but becomes especially slow in adults such that some individuals may only grow a few tenths of a mm each year. In northern states, distinct growth-and-rest

lines may be evident in the shell (reflecting rapid summer and slow winter growth) and may be counted as annuli to determine age. However, in Texas waters, growth-and-rest lines are not necessarily annuli. Hot summer droughts may cause growth checks to appear that resemble winter rest lines or mild winters may allow growth throughout the year. Limits to age and growth in Texas remain unclear. Nonetheless, large heavy-shelled species known to be long-lived and slow-growing elsewhere are believed to have similar growth patterns locally in Texas waters. Therefore, although populations can be quickly and easily harmed, they may require long periods of time to recover.

### **Habitat Requirements**

Freshwater mussels in Texas occur in rivers and streams, Caddo Lake (the only natural lake in the state), reservoirs, ponds, and canals and in still waters to those of moderate flows. They can occur on a variety of substrate types, but most frequently inhabit firm mud, stable sand, and gravel, including combinations of these types. Unionids may occur in relatively shallow waters to depths of many meters, providing dissolved oxygen is present (often a limiting factor in many freshwater reservoirs, especially in summer). Many mussels tolerate wide ranges in water temperature as long as extremely hot or cold extremes are avoided and annual fluctuations support normal breeding activity. Unionids usually require environments that are very stable over long periods of time. Many freshwater mussels are exceptionally intolerant of changes to their environments, including modifications to terrestrial ecosystems sometimes well removed from their immediate aquatic locations.

Often it is easiest to characterize unacceptable mussel habitats including: deep shifting sand (slow moving unionids cannot maintain positions in rapidly moving substrates), deep soft silt (they may sink and smother), scoured cobble and bedrock (where they cannot dig in or may be easily swept away), severe long-term dewatering due to drought or drawdown (that exposes them to temperature extremes, desiccation, precludes feeding, etc.), dramatically fluctuating water levels (mussels move slowly and cannot respond quickly), dense beds of aquatic macrophytes (that confound digging into the substrate, reduce phytoplankton food sources, and may be oxygen deprived at times), substrates covered with algal layers or sticks and leaves (confound movement, may block feeding and breathing), low-quality polluted waters (many are very intolerant of pollution), saline waters (only two species tolerate even minimal levels of salinity), lack of host fishes (that are necessary for reproduction), and, for some species, impounded waters (many species require flowing waters and cannot survive in reservoir conditions) (Howells 2004b). Unstable banks that collapse and would cover unionids living below are also unacceptable habitat. Many unionids are sensitive to disturbance during brooding and may abort marsupial eggs and developing glochidia if touched, moved, or agitated. Some species are negatively impacted by silt-laden turbid waters that can clog gills or preclude host fishes seeing female lures or conglomerates containing glochidia. Singly or in groups, all these issues are often major hallmarks of human impacts on aquatic environments and therefore, on freshwater mussels.

### **Importance in Aquatic Ecosystems**

Though often unseen by laymen and ill-regarded by some resource managers until recent decades, freshwater mussels are extremely important components of freshwater ecosystems. Where healthy populations do actually remain, unionids are often the single greatest component of system biomass with more kg of mussels than all other animal species (Negus 1966). Because of the extreme longevity of many species, they provide long-term nutrient and energy flow storage and release stability (Nedean et al. 2000, undated).

Filter-feeding activity can produce very significant impacts on water quality by removal of algae, biological and non-biological particulates, and even toxic environmental contaminants (Strayer et al. 1999; Nedean et al. 2000; Lyons et al. 2007). For example, mussels in a Polish lake were estimated to filter 79% of the lake volume and remove some 11.5 tons of material from the water during the growing season (Kasprzak 1996) and freshwater mussels in the Hudson River were calculated to filter daily amounts of water equal to the river discharge volume (Strayer et al. 1994).

Freshwater mussels also contribute to sediment turn-over much as earthworms do in terrestrial situations. Dense assemblages may provide some degree of substrate stability during times of high water and flood-scour events. They also provide substrates on which other clinging or epiphytic organisms may grow. Additionally, freshwater mussels often support large and diverse populations of parasitic and commensal organisms within their

mantle cavities. Indeed, some water mites and midge fly larvae only occur within native mussels. When mussels are lost, countless other organisms are lost as well. Unionids are important food items for numerous species including muskrats (*Ondatra zibethicus*) and other shellfish eating mammals, some birds, and fishes including freshwater drum, catfishes (*Ictalurus* and *Ameiurus*), and others.

## Fisheries and Harvest

Native Americans harvested freshwater mussels for food, used their shells as tools and for ornaments, and valued freshwater pearls some species produced (Howells 1996; Howells et al. 1996; Parmalee and Bogan 1998; Williams et al. 2008). In the 1890s, major commercial fisheries developed throughout the Mississippi River basin for mussel shells used to make pearl buttons; however, declining mussel abundance and development of plastics largely ended this fishery by the mid-1900s (Howells et al. 1996; Parmalee and Bogan 1998; Williams et al. 2008). Although Texas had commercially desirable mussel populations, it was geographically too far removed from major button factories in Iowa, Illinois and other states and transportation too costly to support major button fisheries. However, some smaller button-production factories did occur at sites in Texas (Howells et al. 1996). Some freshwater mussels produce valuable gem-quality pearls that have occasionally prompted (and maintained) pearl fisheries, including some in Texas waters (Kunz 1898; Kunz and Stevenson 1908; Howells et al. 1996). Ongoing Texas pearl fisheries are largely focused on the Concho and other tributaries of the Colorado and other Central Texas rivers and reservoirs, with no particularly significant pearl harvest in either the lower Trinity or San Jacinto rivers (Howells 1993; Howells et al. 1996).

In addition to a limited interest in continued pearl harvest in Texas, a major fishery for freshwater mussel shells for use in production of cultured pearl nuclei began to develop in the mid-1900s, with a particular boom in activity in 1991 due to a price war among shell buyers and exporters (Howells 1993; Howells et al. 1996). Demand for mussel shell was high at that time and Texas had few mussel harvest regulations in place and very limited information on the local resource (Howells 1993; Howells et al. 1996). This rapidly expanding fishery ultimately led to Texas Parks and Wildlife Department (TPWD) initiating survey and research activity on freshwater mussels, legislative modifications to licensing, department harvest regulations, and other resource management activities. By the late 1990s, major die-offs among Japanese pearl oysters (used to produce most cultured pearls), increasing protective state and federal regulations, and continuing declines in mussel populations resulted in a dramatic reduction in demand for American mussel shells and corresponding decrease in the number of mussel licenses sold and musselers seeking these animals.

Texas currently has mussel harvest regulations in place, with a series of protective no-harvest sanctuaries and minimum size and bag limits. Limited amounts (by number and weight) can be taken under a fishing license and scientific collection permits can be issued for biological research; however, regulations passed in 2007, now restrict commercial harvest licenses to a very small number of individuals that have historically held such licenses in defined previous years.

## Conservation Status

Freshwater mussels are very sensitive barometers of environmental quality. When ecological conditions in terrestrial or aquatic habitats are modified or degrade, unionids are among the first organisms to decline and, all too often, vanish. As a result, they are the most rapidly declining faunal group in North America (Bogan 1996; Strayer et al. 2004). Current estimates consider some 50 to 80% of U.S. species to be extinct, endangered, or threatened, or will be very soon. Among the approximately 300 North America species, 25% have already been federally listed as endangered or threatened, with another 50% of special concern (Williams et al. 1993; Williams et al. 2008). Some 75% have been considered endangered, threatened, or of special concern at the state level as well (Nedeau et al., undated).

It is important to distinguish between legal listings by state or federal authorities as endangered, threatened, or special concern and actual biological or ecological status. Many organisms may be ecologically endangered or threatened, but have not been legally listed. One and perhaps two species in Texas may have already slipped into extinction without any legal recognition of their declining status. For example, in mid-2009, as TPWD considered

legally listing false spike (*Quadrula mitchelli*) as threatened in Texas, but the American Fisheries Society (AFS) drafted a manuscript that rated the species as "presumed to be extinct" (Williams et al., in preparation). Further, legal listings follow political boundaries and not necessarily biological distributions. Therefore, a species that is legally listed by one state as endangered may be extremely abundant elsewhere.

Based on surveys conducted since 1992, it appears that nearly all unionids native to Texas have been reduced in abundance and distribution over the past 100-150 years. The conservation status of perhaps half of the Texas mussel taxa remains relatively stable, with the remainder obviously less abundant and less widely distributed in recent years. One species has not been found live since 1898 (Howells et al. 1996), another has not been found alive since the 1970s, and living specimens of several mussel species have only been known from 1-5 locations in recent decades (Howells 2009).

Currently, only a single Texas mussel (Ouachita rock-pocketbook, *Arkansia wheeleri*, only known in Texas from two shells found in Lamar County), is actually listed legally under federal and state regulations as endangered. Other species may be ecologically endangered, threatened, or of special concern, but they are not presently covered as such under federal or state regulations. However, a group of species, including a number from Texas waters, is currently under review for federal listing by U.S. Fish and Wildlife Service (USFWS) and others are being considered for state listing by TPWD. Among those species now under review are several reported from the Trinity or San Jacinto rivers, or both.

Protection efforts for Texas mussels include endangered listing for Ouachita rock-pocketbook, selected no-harvest mussel sanctuaries at sites throughout Texas, and sport and commercial harvest regulations (that apply to shells as well living animals and minimum harvest sizes that preclude harvest of some species that never grow large enough to be legally taken). However, no recovery or management plans are apparently in place at this time and there is often little or no protection from impacts other than direct harvest.

## MUSSEL STUDIES IN TEXAS

Despite the ecological and economic importance of freshwater mussels, the group drew rather limited attention until relatively recently. Early boundary water and other survey efforts sometimes included collections of freshwater mussels in the 1800s. Strecker (1931) prepared a review of collection records from Texas waters available at that time. In subsequent decades, Parks (1939), Bachtel (1940), and Parks and Bachtel (1940) described eastern Texas unionids or conducted surveys of several eastern Texas waters, including sites in the Trinity River basin and several brief manuscripts were published on mussels from the upper reaches of that drainage (Read and Oliver 1953; Read 1954; Flook and Ubelaker 1972; Mauldin 1972). More recently, in the 1960s and 1970s, H.D. Murray (Trinity University, San Antonio) made collections statewide and produced several publications on Texas unionids. In the 1970s and 1980s, R.W. Neck (Houston Museum of Natural Science, HMNS) and A. Metcalf (University of Texas at El Paso) also initiated mussel collections and surveys, with several resulting publications. From the late 1960s through the 1990s, C.M. Mather (University of Science and Arts of Oklahoma, USAO, Chickasha) and J.A.M. Bergmann (U.S. Department of Defense, San Antonio) made extensive collections of freshwater mussels throughout Texas. Also, in recent decades, W.H. McCullagh (Jacksonville, Florida) collected Texas unionids.

The price war that broke out among shell buyers (purchasing freshwater mussel shells to produce implant nuclei for creation of cultured pearls) and subsequent high prices prompted hundreds of resident and non-resident musselers to begin harvesting in Texas waters where few regulations were in place (Howells 1993). In response to this rapidly expanding fishery, TPWD's Inland Fisheries Division instructed R.G. Howells at its Heart of the Hills Fisheries Science Center (HOH; then, Heart of the Hills Research Station) to initiate studies of this resource in 1992. The HOH staff began statewide surveys of mussel distribution and abundance, research on mussel biology and taxonomic genetic studies, and development of an array of written materials, including technical reports, scientific journal articles, and educational publications. Collaboration with Neck and Murray produced the book "Freshwater Mussels of Texas" (Howells et al. 1996; but sent to press in 1994) and with Mather and Bergmann to produce a 1995 symposium proceeding presentation on rare Texas unionids (Howells et al. 1997) and a journal article on eastern Texas taxa (Howells et al. 2000). Howells (1997) also summarized current information on freshwater

mussels of the Big Thicket, including the Trinity and San Jacinto drainages. These publications were able to combine collection records from the Houston Museum of Natural Science (HMNS), Trinity University collection (TUC), University of Science and Arts of Oklahoma (USAO), and personal data relating to Texas mussel surveys.

From 1992 through 2006, HOH produced annual mussel survey reports to document ongoing data development in Texas, with particularly noteworthy efforts in 1994, 1995, and 1996 (note that some publications predated these reports). Although the TPWD administration dramatically reduced HOH mussel research in 1997, some work continued through HOH and other individuals within and outside TPWD provided information on the status of Texas unionids on an ongoing basis. In 2004, State Wildlife Grant (SWG) funding became available to support new surveys of locations around Texas previously found to support either particularly diverse and abundant populations, very rare mussel species, or both. Field research in 2005 and 2006 conducted by staff of Stephen F. Austin State University (conducted by A.Y. Karatayev and L.E. Burlakova) and Laredo Community College (conducted by T. Miller) were summarized and compared to previous data (Howells 2006). In subsequent years, Karatayev and Burlakova conducted additional SWG-funded and other studies at selected sites in Texas (Karatayev and Burlakova 2007; Burlakova and Karatayev 2008). Other field work with freshwater mussels in eastern Texas has also been undertaken by University of Texas at Tyler (Ford and Nicholson 2006; Ford and May, undated) and C.R. Randklev and others from North Texas State University (manuscripts in press).

In 1998, HOH and TPWD Wildlife Diversity Division personnel created a volunteer Mussel Watch program with the goal of having trained volunteers provide additional field data on Texas freshwater mussels. However, by mid-2000, HOH withdrew from the program due to concerns about some Mussel Watch generated information. Some initial data were included in annual HOH reports, but although the Mussel Watch program has continued, most such volunteer information was not incorporated in subsequent HOH reports and publications.

Following retirement from TPWD in 2006, R.G. Howells continued field work, writing, consulting, and collaboration with others on issues related to freshwater mussels. In response to questions about species status from TPWD, USFWS, Wild Earth Guardians, and others, Howells released a biological opinion to address the conservation status of rare mussels in Texas, including generally rare taxa, those under consideration for federal listing, and TPWD's no-harvest mussel sanctuaries (Howells 2009). He is currently one of a group of researchers working through the AFS on the taxonomy and conservation status of U.S., Canadian, and Mexican unionids to update the previous Williams et al. (1993) paper on conservation status and distribution (Williams et al., in preparation).

A number of university thesis projects resulted in publications on Texas unionids in recent years. Ansley (1998) addressed mussels at two survey sites in the Lake Creek tributary of the West Fork of the San Jacinto River. Feaster (1998) discussed unionids in streams in Angelina and Davy Crockett National Forests in eastern Texas. Bordelon and Harrel (2004) reported on the Village Creek drainage in Hardin County.

More recently, Howells began creation of a database related to unionids survey and collection records from Texas waters and important data from adjacent states. This includes the TPWD Management Data Series (MDS) annual survey reports and other MDS reports, SWG reports, unpublished databases of (Mather, Bergmann, McCullagh, and others), journal articles and technical reports, M.S. theses, and available museum and university collection records. This growing database includes ca 13,000 entries to date and was used to develop information in this report. Additionally, TPWD staff in conjunction with Karatayev and Burlakova (Buffalo State College, NY) also report developing a mussel database for Texas waters as well (not reviewed for use in this report).

## **SPECIMEN IDENTIFICATION AND SHELL CONDITION**

It is important to recognize that knowledge of freshwater mussels, their identification and biology, and ecological status has evolved dramatically over the past 20-30 years. Not only has scientific study of these organisms in Texas expanded since 1992, but biochemical genetic analysis (initially electrophoresis and now DNA studies) employed since the mid- to late 1990s have both clarified and modified understanding of unionids. Some identifications and beliefs of early workers are now known to have been incorrect. This has been particularly problematic for species that have been rather rare in Texas so that even mollusk experts were unfamiliar with the

degree of morphological variation and extent of their actual distribution. Therefore, caution should be employed in directly following older literature without also checking the results of more-recent research.

Unlike some organisms that leave little trace behind after their deaths, freshwater mussels and other bivalve mollusks often leave shells, valves, or fragments of those structures as evidence of their past presence. Some such structures may remain for years, decades, or centuries after death. Although it is not usually possible to determine the exact time since death, qualitative estimates based on shell condition can nonetheless be extremely useful. Some publications have used terms including fresh, weathered, and subfossil to describe the condition of bivalve hard parts. Howells (2004) presented a more-detailed classification series of terms. These included "very recently dead" for shells and valves with soft tissues still remaining attached, "recently dead" for those appearing as though a living specimen had been killed and cleaned of soft parts, to "subfossil" for specimens with little or no shell epidermis remaining, both interior and external surfaces bleached white and chalky, and often with algal growth, staining, or calcium deposition. Although exact time periods since death cannot be assigned to such material, collection of shells with soft tissues attached (soft tissues often persist for only 1-2 weeks following death) can be an indication that the species in question may still exist in the area even if living specimens have not been located. Conversely, if only bleached, chalky-white valves and fragments can be found, it may be reasonable to conclude that the species may have existed in the area at one time, but that there is no confirmation that it is still present. Studies that only document living specimens without also addressing dead shells, valves, and fragments cannot fully characterize the historic mussel assemblages at study sites or fully evaluate what may still remain.

Note too that gravel and shell deposits have been mined for use as road fill, boat ramps, and the like. As a result, shells and valves of species like Asian clams and rangias may appear at sites around the state. This may occur with unionids shells, but much less frequently so. Presence of shell material at a particular site is not necessarily a guarantee that a given species actually occurred there or is present now.

## **FRESHWATER MUSSELS OF THE TRINITY AND SAN JACINTO RIVERS, TEXAS**

The Trinity River runs from north, northwest, and northeast of the Dallas-Fort Worth area roughly southeasterly and enters Galveston Bay east of Houston, with an extensive drainage basin that crosses a number of different terrestrial ecosystems. Conversely, the San Jacinto River drains a much smaller region north and northwest of Houston in southeastern Texas, with two major branches and several larger tributaries. The San Jacinto River reaches upper Galveston Bay just west of the Trinity River. Both systems have been impounded at multiple sites. Buffalo Bayou drains a much smaller area from coastal prairie west of Houston through that city to Galveston Bay. All three systems support freshwater mussel fauna similar to the Neches-Angelina and Sabine systems to the east and distinctly different from the Brazos, Colorado, and Guadalupe-San Antonio basins to the west.

### **Freshwater Mussels of the Trinity River: Overview**

Historically, no system-wide inventories of unionids mussels in the Trinity River have been conducted. A number of studies reported species found at specific sites in the upper Trinity drainage (Read and Oliver 1953; Read 1954; Flook and Ubelaker 1972; Maulden 1972; Neck 1990). Even less information has been available for the central and lower reaches of the basin.

Strecker (1931) summarized collection records and museum specimens earlier in the last century made throughout the system. Howells et al. (1996) briefly addressed the Trinity River and Howells (1997a) included comments through association with the Big Thicket ecosystem. Mussel field surveys conducted by TPWD from 1992 onward included sampling and specimen records from numerous sites in the system, with a summary of selected areas in Howells (2006). Data generated by C.M. Mather, J.A.M. Bergmann, W.H. McCullagh, and others were included in many of the TPWD annual reports as well. More recently, C.R. Randklev and others from North Texas State University have examined sites in the upper reaches of the Trinity River and its branches.

In July 1993, TPWD conducted freshwater mussel surveys in the Trinity River from the boat ramp area below the dam at Lake Livingston downstream to the mouth of Mussel Shoal Creek and in several other tributary streams in the area (Howells 1995). In July 1995, sites in the Trinity River below Lake Livingston were again examined by TPWD to an area below the mouth of Mussel Shoal Creek, downstream of SH 106, up- and downstream of US 90, and downstream of I-10, and at sites in Mussel Shoal Creek and other tributaries (Howells 1996b). Although long-dead and subfossil shells and valves from an array of unionids were taken along the main channel of the Trinity River at sites downriver to the vicinity of Mussel Shoal Creek during these efforts, four southern mapleleaf specimens (*Quadrula apiculata*) were the only living mussels found (Howells 1995). Main channel areas at downstream sites generally produced no bivalve remains. In 1996, C.M. Mather and J.A.M. Bergmann examined sites in the Trinity River upstream of Lake Livingston and found an assemblage of unionids species actively reproducing in that area (Howells 1997b). Other unionid populations still persist in Lake Livingston itself (see summary in Howells 2006). Additionally, a localized living mussel assemblage was found in 2006 at FM 3278 immediately below the dam at Lake Livingston (see Internet photos at <http://dan-johnson.net/bivalves>; D. Johnson, pers. comm., June 2009); however, this site information has not been published and apparently not reexamined more recently.

Strecker (1931) commented on chemical contamination in the upper Trinity River "in recent years" may have been responsible for apparent extinctions there. Strecker (1931) also provide a list of mussel species from the Trinity River drainage, as well as list specific to the Elm Fork in the upper basin and Mussel Shoal Creek downstream of Lake Livingston. However, a number of species listed by Strecker have been synonymized, reclassified, or considered invalid. Based on Howells (1997a, 2006), Howells et al. (1996), and information in the Howells database, at least 33-34 unionid species have been reported in the Trinity River basin, with 15-16 species from the lower Trinity River (Table 1) and 25-26 species from tributaries and oxbows in the lower Trinity River drainage (Tables 1-2). At least four species have been introduced in the Trinity River basin (two are apparently established) and several others may potentially occur as well. Taxonomic validity of species in several cases has yet to be resolved with biochemical genetic analysis.

Among the declining species of interest reported in the Trinity River drainage are Texas pigtoe (*Fusconaia askewi*), sandbank pocketbook (*Lampsilis satura*), Texas heelsplitter (*Potamilus amphichaenus*), and Louisiana pigtoe (*Pleurobema riddellii*). Earlier reports of Texas fawnsfoot (*Truncilla macrodon*) from the Trinity River are based on misidentified fawnsfoot (*T. donaciformis*) specimens. However, none of these are currently known to support populations in the Trinity River downstream of the dam at Lake Livingston. There is an early record of Wabash pigtoe (*F. flava*) from Big Creek, Shepherd, (Strecker 1931) that may have been Texas pigtoe, but there is no confirmation of specimens in the main channel of the lower Trinity River. Sandbank pocketbook is appears only to have been reported in the Trinity River basin by Bachtel (1940) from Anderson County far upriver. Texas heelsplitter occurred and may still persist in the upper river reaches in the Dallas-Fort Worth area (Neck and Howells 1994; Howells 2006, 2009) and in reaches above and within Lake Livingston (Howells 1997a, 1997b, 2006, 2009). The species was reported in 1902 (Frierson 1902; Strecker 1931; Neck and Howells 1994) in the lower Trinity River near Shepherd, but seems not to have been documented in that area since. Louisiana pigtoe was also known from upriver sites in the Dallas-Fort Worth area (Strecker 1931) and a past collection in Anderson County (Bachtel 1940), but is not known to be present in the lower river reaches and Strecker (1931) suggested it may already be extinct in the system.

Restricted and difficult access issues have contributed to limited attention by scientists and resource managers (Howells et al. 1996). Some of the lower-most reaches of the Trinity River and associated tributaries and oxbows have either never been surveyed for freshwater mussels, had collection results published, or both. A brief collection in Davis Bayou, Liberty County, in 2000 produced shells of 10 unionid species, some of which were recently dead (Howells 2001a) indicating that some noteworthy mussel populations still persist in the lower Trinity River drainage. However, there is no indication or anticipation that major large mussel assemblages still occur in the lower Trinity River downstream of Lake Livingston or that significant populations of rare mussel species of concern persist here. Not only has much of the main channel area been subject to anthropogenic modification and disturbance, but these activities have created unstable banks and shifting-sand bottoms that are unacceptable mussel habitat in many areas. Shell remains examined at depositional sites downstream of Lake Livingston have produced long-dead and subfossil specimens that confirm that mussel populations occurred here in the past, but there has been little evidence of either living unionids or recently dead shells and valves to suggest that noteworthy. However, small, but as yet undiscovered populations may still occur locally.

## Freshwater Mussels of the San Jacinto River: Overview

The San Jacinto River basin is a relatively limited in drainage area placed largely north and northwest of Houston in southeastern Texas. It includes a West Fork the runs from origins northwest of Conroe in Walker County, through Lake Conroe west of that city, and proceeds southeast into Lake Houston. The East Fork San Jacinto runs from eastern Walker County generally southward to the Cleveland area and into Lake Houston just east of the West Fork San Jacinto River. Luce Bayou runs just east of the East Fork San Jacinto River and enters the northeast side of Lake Houston. Another tributary, Clear Creek, runs roughly from west to east and also enters Lake Houston on the west side. Below the dam at Lake Houston, the lower San Jacinto River moves generally southeast around northeastern Houston and enters Galveston Bay east of the city and just west of the Trinity River mouth.

Strecker (1931) discussed the noteworthy abundance and diversity of unionids found in this system, including unique ecophenotypes of some. Unfortunately, due to anthropogenic activities associated with urban expansion of the Houston metroplex and extensive habitat modification often associated with sand mining and tree removal, some of these have not been documented in many years.

In the 1970s and 1980s, C.M. Mather and J.A.M. Bergmann sampled several sites on the East Fork and West Fork San Jacinto River, with even earlier collection records for specimens in the OSUM collection. Because of its proximity to the Houston Museum of Natural Science and interest in local malacology associated with that facility, museum staff had a particular interest in mussels in the system and made collections there, including with the assistance of individuals associated with the American Malacological Union (now American Malacological Society) in the early 1970s (R.W. Neck, pers. comm.; C.E. Boone, pers. comm.). Unfortunately, much of this information is not available in published literature and only a limited number of these records are currently included in the RGH database.

Howells et al. (1996) alluded to low-water conditions in the 1980s (prior to TPWD mussel survey activity) that stranded mussels, but there was apparently little documentation of impact on unionids. In 1999, major areas of Lake Houston were dewatered and vast numbers of freshwater mussels were stranded according to reports by callers that contacted HOH (Howells 2000). However, no TPWD efforts were initiated to document these reports. When the upper reaches of Lake Houston were surveyed again in 2005 (Howells 2006), seven species in that area were found to have survived.

The West Fork San Jacinto River was surveyed by TPWD from sites upstream of Lake Conroe, though that reservoir, downstream to locations below US 45 south of Conroe, and at a number of locations in the East Fork of the San Jacinto in 1994 (Howells 1996c). In 1996, TPWD staff also examined sites upstream of Lake Conroe and the lower reaches of the West Fork San Jacinto River from US 59 upstream to the vicinity of FM 242, as well as Spring Creek and Lake Houston (Howells 1997b). Ansley (1998) reported unionids specimens located at sites on the Lake Creek tributary. Generally, the TPWD efforts found living unionids in Lake Conroe and at a few sites within the West Fork San Jacinto River itself. However, much of this river had been badly modified by anthropogenic activities including extensive sand mining and land development. Much of the resulting river bottom habitat had been smothered by deep, shifting sands (unacceptable mussel habitat) restricting surviving mussels to limited areas of microhabitat where they could still survive. The USAO collection contains material from Winters Bayou, a West Fork tributary, found in 1990. The upper reaches of the East Fork in the Cleveland area were often degraded by human activities. Most of the central and lower runs of the East Branch San Jacinto River have not been formally surveyed for the presence of possible mussel populations.

Collectively, these studies and reports indicate some 28-29 unionid species have been reported in the San Jacinto River drainage (Table 1); numbers documented in various forks, tributaries, and reservoirs is presented in Table 2. Among these species, only Louisiana pigtoe (*Pleurobema riddellii*) is currently being considered for state and federal listing; however, no living or recently dead specimens have been confirmed in this basin in many years. Indeed, "fresh" material last found in 1986 (USAO 3515) may record the last confirmation of this species in the San Jacinto River system. Other species in these waters may be ecologically rare, but are not proposed for federal or state listing at this time.

To assist university staff and others with 2005 and 2006 surveys, the Howells (2004c) identification guide was prepared to describe unionids species documented from the San Jacinto River and adjacent Buffalo Bayou.

### Freshwater Mussel Species in the Study Area: Species Summaries

The following species discussions have been summarized from Howells (2004c), Howells et al. (1996, 1997), as well as other publications summarized in those sources and additional unpublished records in the author's database. Information from species that range into areas outside Texas has included material from Murray and Leonard (1962), Clarke (1981), Oesch (1984), Cummings and Mayer (1992), Vidrine (1993), Watters (1993), Strayer and Jirka (1995), Parmalee and Bogan (1998), Sietman (2003), and Williams et al. (2008). Additionally records were included from the following mollusk collections: Academy of Natural Sciences of Philadelphia (ANSP), Ohio State University Museum of Biological Diversity (OSUM), Trinity University Collection (TUC), Dallas Museum of Natural Science (DMNS), University of Science and Arts of Oklahoma (USAO), and University of Michigan Museum of Zoology (UMMZ), as well as other data. Species are listed alphabetically by scientific name.

**Threeridge (*Amblema plicata*):** Threeridge occurs in Texas from the lower Nueces River north and northeast through the major drainage systems in Texas and throughout the Mississippi River basin and into the Great Lakes. It has been reported in the past two decades at multiple sites on numerous occasions in the central and upper Trinity River drainage. However, since TPWD surveys began in 1992, the only records from the lower Trinity River have been of subfossil specimens. The species is still present in the San Jacinto River basin with living specimens found in Lake Houston in 2005 (Howells 2006). Throughout its range, AFS considers this species to be stable (Williams et al., in preparation).

**Flat floater (*Anodonta suborbiculata*):** This species is apparently not native to Texas waters. Strecker (1931) found no records of it, but noted its presence in nearby Louisiana. Historically it ranged throughout the Mississippi River basin and east to Alabama and northeastern Georgia. However, as reservoirs were constructed in Texas (and elsewhere) and more favorable habitat was created, flat floater was able to invade as far west as Possum Kingdom Reservoir (Mather et al. 1990; Howells et al. 1996; Howells 2008). It has been found at sites in Trinity and San Jacinto drainage (Howells et al. 1996; Howells 2006; Mather et al. 1990). Some specimens in Texas waters are morphologically atypical (Howells et al. 1996; Howells 2008); however, recent morphometric and genetic studies have failed to find significant differences between flat floaters in Texas and those from other states (Williams et al. 2009). Throughout its range, AFS considers this species to be stable (Williams et al., in preparation).

**Rock-pocketbook (*Arcidens confragosus*):** Rock-pocketbook is typically widely distributed, but rarely abundant throughout its distribution. In Texas, it occurs from the lower Guadalupe River into systems to the north and east. Trinity River records are generally from the central and upper reaches and it was reported alive upstream of Lake Livingston in 1996 (Howells 1997b). Its range extends north and east to southern Minnesota and West Virginia. Very-recently dead material was documented in Davis Bayou, Liberty County, in 2000 (Howells 2001a) suggesting the species still persists in some tributaries of the lower Trinity River, but without records from the lower Trinity River itself. Within the San Jacinto River, collection records are from 1968 or earlier, with none reported in surveys in the system in several decades. Throughout its range, AFS considers this species to be stable (Williams et al., in preparation). Howells (2009) suggested it be considered of special concern in Texas due to its widely distributed limited numbers and major losses recently in the central Neches River.

**Tampico pearlymussel (*Cyrtornaias tampicoensis*):** This mussel is native from the Brazos River south and west into northeastern Mexico (Howells et al. 1996; Howells 2003). It has been introduced unsuccessfully in the upper Trinity River (Howells et al. 1996; UMMZ 60822, Trinity River, 1934; UMMZ 246829; Lake Lewisville, 1952; note: the author has not examined the UMMZ specimens and it is possible they may be misidentified bluefer, *Potamilus purpuratus*) and the Lost River reach of the lower Trinity River (Howells and Tirpak 2003). This species is known for production of an exceptional number of gem-quality pearl (Howells 1996a)...a fact that may relate to its introduction outside its native range. Tampico pearlymussel populations in Texas have adapted well to man-made reservoirs (no natural lakes were present historically in its range) and its abundance in Texas may be greater at

present than if no impoundments had been built. However, a Mexican subspecies (*C. t. tecomatensis*) is listed by USFWS as endangered (Howells 2001b).

**Texas pigtoe (*Fusconaia askewi*):** Texas pigtoe ranges from the San Jacinto and Trinity rivers into the Neches-Angelina, Sabine, and Big Cypress (presumably) systems of eastern Texas, into western Louisiana, and apparently southern Arkansas. Although it has declined dramatically in abundance in the past few decades, recent surveys in the upper Sabine River have found it somewhat more numerous there than once thought (Ford and Nicholson 2006; Ford and May, undated). A pigtoe population was found in 1996 in the Trinity River upstream of Lake Livingston that is apparently this species (Howells 1997a, b); however, the only recent records from the lower Trinity River are of subfossil specimens (Howells 1995, 1996b). Fusconaid pigtoes in the San Jacinto River are often more elongate than typical of this species; however, others are more similar to Wabash pigtoe, but no genetic studies have been conducted to date to clarify the identity of San Jacinto basin pigtoes. A collection was made in the West Fork San Jacinto River in 2005 (W.H. McCullagh; pers. comm.). Throughout its range, AFS considers this species to be vulnerable (Williams et al., in preparation) and, in Texas, Howells (2009) also recommended it be listed as vulnerable.

**Wabash pigtoe (*Fusconaia flava*):** This pigtoe is often one of the more common fusconaid in the Mississippi River basin. It has been reported in Texas, particularly in the past, but to date, no genetic studies have been completed to confirm that true Wabash pigtoe does actually occur in Texas waters. Strecker (1931) listed this species from several sites in the upper Trinity River drainage and unidentified fusconaid have been reported at a number of sites scattered throughout the Trinity River. Charles Randklev (University of North Texas, Denton; pers. comm.) collected living specimens in the Trinity River, Anderson County, in 2008 that are morphologically similar to Wabash pigtoe, but no living populations are currently known at down-river locations. In the San Jacinto River, records of pigtoes called Wabash pigtoe are from 1986 or earlier. However, Ansley (1998) collected several living specimens in lower Lake Creek upstream of the West Fork San Jacinto River that also somewhat resembled Wabash pigtoe. Neither the Randklev nor Ansley specimens have been subject to genetic identification confirmation to date. Throughout its range, AFS considers this species to be stable (Williams et al., In Press). Howells (2009) indicated that, if Wabash pigtoe does indeed occur in Texas at all, it should be considered rare.

**Round pearlshell (*Glebulina rotundata*):** Round pearlshell is a species typical of the lower reaches of coastal rivers, often near the fresh-salt water interface. It has been reported from the lower Guadalupe River northeastward along the coastal counties in Texas and eastward along the Gulf States to northwestern Florida. No published collection records of this species were found during preparation of this report from waters of the Trinity River. However, it almost certainly occurs in the lower Trinity River drainage, particularly in local bayous and canals (most of which have never been surveyed regarding mussel populations) and D. Johnson found this round pearlshell in a limited area immediately below the dam at Lake Livingston in 2006 (pers. comm.; photo at [http://dan-johnson.net/bivalves/round\\_pearlshell.html](http://dan-johnson.net/bivalves/round_pearlshell.html)). In the San Jacinto River, Strecker (1931) reported material from the lower San Jacinto River in Harris County, but no more-recent records were located. Recently-dead round pearlshell was found upstream in the West Fork San Jacinto River upstream of Stubblefield in Walker County in 1996 (Howells 1997b). Its presence in even urban stretches of canals and bayous in the Buffalo Bayou and Brazos River waters of Harris County suggest the species likely persists in the lower drainage of the San Jacinto system as well. Throughout its range, AFS considers this species to be stable (Williams et al., in preparation). Howells (2009) recommended round pearlshell in Texas be considered of special concern because of extensive development, urbanization, and modification of coastal habitat areas.

**Louisiana fatmucket (*Lampsilis hydiana*):** This unionid has been reported historically and in recent surveys at numerous sites in the upper, central, and lower tributaries of the Trinity River and within the San Jacinto River basin. However, no living specimens have been documented in the main run of the lower Trinity River in recent decades. Throughout its range, AFS considers this species to be stable (Williams et al., in preparation) and it is often locally abundant at sites in Texas.

**Sandbank pocketbook (*Lampsilis satura*):** Sandbank pocketbook ranged from the San Jacinto River throughout eastern Texas and into Louisiana and Arkansas, but has been lost or reduced in abundance at locations in Texas. Within the Trinity River, there appears to be only a single record from 1939-1940 collections by a Bachtel (1940), a graduate student, who reported it from Campbell Lake upriver in Anderson County. Given that this species is otherwise not known from impounded waters in Texas and Louisiana fatmucket specimens in the area are

sometimes extremely massive in shell development, the identification of Bachtel's material may be questionable. In the San Jacinto River, sandbank pocketbook has not been reported alive since 1970, with only weathered shells found in collections made in 1986 and 1996. It is therefore doubtful if this species still persists in either the Trinity or San Jacinto rivers. Throughout its range, AFS considers sandbank pocketbook to be threatened (Williams et al., in preparation) and Howells (2009) also recommended it be considered threatened in Texas.

**Yellow sandshell (*Lampsilis teres*):** This mussel occurs in all the major drainage basins from the Rio Grande to the Red River in Texas, except some extreme northwestern areas. Yellow sandshell has been reported on numerous occasions from many sites in the Trinity and San Jacinto rivers. Recently dead material was found in Mussel Shoal Creek in the lower Trinity River drainage in 1993 (Howells 1995), but otherwise it has not been documented in the lower river drainage in several decades. It may still persist in some canals, bayous, and oxbows in lower reaches of the Trinity and San Jacinto rivers that have not been surveyed (at least in recent years). Throughout its range, AFS considers yellow sandshell to be stable (Williams et al., in preparation) and it can be locally abundant at sites in Texas.

**White heelsplitter (*Lasmigona complanata*):** White heelsplitter reaches its southwestern range limit in northeastern Texas and extends north to southcentral Canada and east to Pennsylvania and Alabama. Unsuccessful introductions occurred in the lower San Marcos River and upper Trinity River drainage (Neck 1990; Howells et al. 1996). It is not currently expected in either the lower Trinity or San Jacinto rivers. Throughout its ranges, AFS considers the species to be stable (Williams et al., in preparation). In Texas, Howells (2009) recommended it be considered endangered because of it is apparently restricted to Lake Texoma and one or two streams in Lamar County. The Lake Texoma population is now at risk from zebra mussel (*Dreissena polymorpha*) that has been found introduced there in 2009 and the downstream populations in Lamar County may soon be threatened as well.

**Fragile papershell (*Leptodea fragilis*):** This unionid occurs from the Colorado River drainage north to Minnesota and the St. Lawrence and east to northeastern Georgia. It has been reported at numerous sites on many occasions in the central and upper Trinity River drainage and several occasions and locations in the San Jacinto River. Recently dead material was found in Davis Bayou in Liberty County in 2000 (Howells 2001a), but there appear to be no recent records of living specimens from the lower Trinity River itself. Throughout its range, AFS considers the species to be stable (Williams et al., in preparation).

**Pond mussel (*Ligumia subrostrata*):** Pond mussel ranges from the lower Guadalupe River drainage (with a record from the Nueces River) north to Minnesota and western Ohio and east to western Alabama. The species has been documented on several occasions at a number of locations in the up-river areas of the Trinity River and Strecker (1931) reported it from Liberty County. Within the San Jacinto River basin, there is a record of recently dead material found in the West Fork San Jacinto River upstream of Stubblefield in 1996 (Howells 1997b). However, this species is likely far more common than these collection records indicate due to presence in ponds, canals, and bayous on private lands that are difficult for biologists to access. Throughout its range, AFS considers this species to be stable (Williams et al., in preparation).

**Washboard (*Megalania nervosa*):** Washboard occurs from the lower Nueces River north through much of the Mississippi River drainage to southern Canada. There appear to be no recent records of living or recently dead specimen from the central and upper Trinity River basin and recent records from the lower Trinity River and its tributaries seems restricted to subfossil shells and valves that died long ago. Washboard has been found at sites in the San Jacinto River drainage, with living animals found in Lake Houston as recently as 2005 (Howells 2006). Washboard is a larger stream and river species (that tolerates impoundment) that is often restricted to coastal plain and lower-river reaches. Despite its slow growth, large size, commercial-harvest importance, and slow-recovery from disturbances, AFS considers this species to be stable throughout its range (Williams et al., in preparation).

**Threehorn wartyback (*Obliquaria reflexa*):** This mussel ranged from Mussel Shoal Creek in the lower Trinity River drainage north to Canada and waters west of the Appalachians. Strecker (1931) reported it from Mussel Shoal Creek near Shepherd, but subsequent surveys by TPWD in that area failed to find it. However, D. Johnson found this species at a site immediately below the dam at Lake Livingston in 2006 (pers. comm.; photo at [http://dan-johnson.net/bivalves/threehorn\\_wartyback.html](http://dan-johnson.net/bivalves/threehorn_wartyback.html)). Otherwise, threehorn wartyback seems largely absent from the remainder of the Trinity and San Jacinto drainages. It is often common in other waters to the north and east. Throughout its range, AFS considers this species to be stable (Williams et al., in preparation).

**Bankclimber (*Plectomerus dombeyanus*):** Bankclimber ranges from the San Jacinto River north through eastern Texas through the Mississippi River valley to southern Illinois and into the Tennessee River system. In the Trinity River, bankclimber has been found at sites upstream of Lake Livingston. In the Trinity river downstream of Lake Livingston, surveys in recent years produced only subfossil shells and valves. It has been found at locations in the San Jacinto River basin, including documentation of living specimens in Lake Houston in 2005 (Howells 2006). Bankclimber may be expected in oxbows, canals, and bayous in the lower Trinity and San Jacinto drainages that have not yet been surveyed. Throughout its range, the AFS considers it to be stable (Williams et al., in preparation).

**Louisiana pigtoe (*Pleurobema riddellii*):** This unionid ranged from the San Jacinto River north and east through the Trinity, Neches-Angelina, Sabine, and Big Cypress drainages into western Louisiana and perhaps southern Arkansas. The type locality for Louisiana pigtoe was in the upper Trinity River; however, nearly 80 years ago Strecker (1931) considered it to have been eliminated in the area. In the upriver stretches of the Trinity River reports by Strecker (1931) and Bachtel (1940) were the last reports of this species and no records from the lower Trinity River downstream of Lake Livingston were found during preparation of this report. Within the San Jacinto River basin, Louisiana pigtoe was historically found in both the East and West forks, Lake Creek, and lower San Jacinto River; however, no living or recently dead specimens have been documented in many years, with "fresh" material last found in 1986 (USAO 3515). This species was probably never abundant, but has become extremely rare in Texas in recent decades and no populations are currently known in either the Trinity or San Jacinto rivers. Throughout its range, the AFS considers it to be endangered (Williams et al., in preparation) and within Texas, Howells (2009) also recommended it be considered endangered.

**Texas heelsplitter (*Potamilus amphichaenus*):** This unionid is endemic to the Sabine River of Texas and Louisiana and the Neches-Angelina and Trinity rivers of eastern Texas; it is not known from the San Jacinto River (Neck and Howells 1994). There are numerous records of Texas heelsplitter in the upper Trinity River system and its associated reservoirs (Neck and Howells 1994; Howells 2006) and a living-reproducing population was found in the central Trinity River upstream of Lake Livingston in 1996 (Howells 1997b). The only apparent record from the lower Trinity River drainage was by Frierson (1902) who reported the species from the Trinity River near Shepherd over a century ago (Neck and Howells 1994). This species has declined in abundance throughout its range in recent decades. Additionally, pink papershell (*P. ohiensis*) a closely related sister species (Roe and Lydeard 1998), has appeared in the upper Trinity River in the Dallas-Fort Worth area in recent years (Howells 2006) and may be either displacing Texas heelsplitter or hybridizing with it (Howells 2006). Many of the animals collected in that area now appear to be intermediates between these two species. No biochemical genetic studies have been performed to clarify this situation. It is reasonable to anticipate that pink papershell may eventually move downriver and influence Texas heelsplitter populations in the central Trinity River and Lake Livingston. In addition to issues in the upper Trinity River drainage, only limited numbers survive in the upper Sabine River, and major populations in the central Neches River have been reduced or eliminated since 2006 (Howells 2009). Throughout its range, the AFS considers this species to be endangered (Williams et al., in preparation) and Howells (2009) also recommended it be considered endangered as well.

**Pink papershell (*Potamilus ohiensis*):** Pink papershell occurs in the Brazos River, Big Cypress Bayou, and Red River drainages in Texas (Neck and Howells 1994; Howells et al. 1996) and ranges up the Mississippi River drainage to Minnesota and the Great Lakes and east to Alabama. It was apparently not present in the upper Trinity River system, but, by the early 1990s became established there along with its sister species, Texas heelsplitter (*P. amphichaenus*) (Howells et al. 1996; Howells 2009). Pink papershell has not been documented in the lower Trinity River drainage or within the San Jacinto River. How it gained access to the upper Trinity River is unknown. Possible impacts on Texas heelsplitter or movement downstream in the Trinity River remains to be determined. Throughout its native range, the AFS considers it to be stable (Williams et al., in preparation).

**Bleufer (*Potamilus purpuratus*):** Bleufer ranges naturally from the Colorado River (possibly from the Guadalupe River) basin into other drainages to the north and east in Texas, with introduction in the lower Nueces River drainage and central Rio Grande (Howells 1997c). Elsewhere it ranges north to southern Illinois and east to Alabama and northwestern Georgia. Within the Trinity River, there are numerous records from the central and upper reaches. Living specimens were found in Mussel Shoal Creek in the lower Trinity River drainage in 1995 (Howells 1996b), but no living populations are currently known in the lower Trinity River itself. This species is also

known from multiple records throughout the San Jacinto River system as well. Bleufer can be locally abundant in Texas and elsewhere. Throughout its range, the AFS considers it to be stable (Williams et al., in preparation).

**Giant floater (*Pyganodon grandis*):** Giant floater ranges through all the major river basins of Texas and north to Canada and east to Georgia. It has been found at numerous locations throughout the upper and central Trinity River system and the San Jacinto River basin. Recently dead material was found in Davis Bayou in the lower Trinity River drainage in 2000 (Howells 2001a), but there are no recent records of collections of living specimens from the lower Trinity River itself. It is almost certainly present in canals, bayous, and oxbows throughout the lower drainages of both the Trinity and San Jacinto rivers. Giant floater can be locally very abundant. Throughout its range, the AFS considers it to be stable (Williams et al., in preparation).

**Southern mapleleaf (*Quadrula apiculata*):** This mussel ranges through all the major river basins of Texas and north to Oklahoma and east to Alabama. It has been found at numerous locations throughout the upper and central Trinity River system and the San Jacinto River basin. Live specimens were found in a tributary of Mussel Shoal Creek in the lower Trinity River drainage in 1993 (Howells 1995) and several living individuals were collected in the lower Trinity River itself a short distance downstream of the dam at Lake Livingston in 1993 (Howells 1995). Southern mapleleaf can be locally abundant. Throughout its range, the AFS considers it to be stable (Williams et al., in preparation).

**Western pimpleback (*Quadrula mortoni*):** This unionid ranges from the San Jacinto River into Texas drainages to the north and east into Louisiana. It has been found at numerous locations throughout the upper and central Trinity River system and the San Jacinto River basin. Very-recently dead material was found in Davis Bayou in the lower Trinity River drainage in 2000 (Howells 2001a), but there are no recent records of collections of living specimens from the lower Trinity River itself. Western pimpleback can be locally abundant and is the most abundant of all the pimpleback-type mussels in Texas. Historically this species was confused with smooth pimpleback (*Q. houstonensis*) and pimpleback (*Q. pustulosa*) (Howells 2002), but genetic studies by Serb et al. (2003) helped clarify its status. Throughout its range, the AFS considers it to be stable (Williams et al., in preparation).

**Gulf mapleleaf (*Quadrula nobilis*):** Gulf mapleleaf ranges from the San Jacinto River system north to the lower Ohio River drainage and east to Alabama. It is associated with a moderate number of records from the central and upper Trinity River system. It was historically reported in the lower Trinity River and associated tributaries, but collections in recent years have been only subfossil shells and valves. However, D. Johnson found this species at a limited site immediately downstream of the dam at Lake Livingston in 2006 (pers. comm.; [http://dan-johnson.net/bivalves/gulf\\_mapleleaf.html](http://dan-johnson.net/bivalves/gulf_mapleleaf.html)). Strecker (1931) listed it from the San Jacinto River in Liberty County, but there have apparently been no subsequent collections in this system. Historical records (and recent sources following archaic terminology) typically listed this species as mapleleaf (*Q. quadrula*) or *Q. aspera* (= *asper*); however, based on genetic analysis, neither is correct (Howells et al. 1996; Williams et al. 2008). This species may still persist at some locations within the lower drainages of the Trinity and San Jacinto rivers that have not been surveyed. Throughout its range, the AFS considers this species to be stable (Williams et al., in preparation).

**Pistolgrip (*Quadrula verrucosa*):** Pistolgrip ranges from the San Antonio River north to Minnesota and New York and east to Alabama and northwestern Georgia. In addition to historical records from the upriver Trinity River waters, living pistolgrip specimens were found upstream of Lake Livingston in 1996 (Howells 1997b). Records from the lower Trinity River and associated waters were listed by Strecker (1931), but apparently without subsequent collections. No published records from the San Jacinto River drainage were found during preparation of this report; however, R.W. Neck (April 1992; pers. comm.) indicated that pistolgrip did occur in the San Jacinto system, but without listing specific details. This species had long been placed in the genus *Tritogonia* until genetic studies confirmed it was actually in the genus *Quadrula* (Serb et al. 2003). This species appears to have declined at some locations in Texas, but throughout its range, the AFS considers pistolgrip to be stable (Williams et al., in preparation).

**Creeper (squawfoot) (*Strophitus undulatus*):** This unionid has been documented from the Concho River, throughout sites in central and eastern Texas, north to the northeastern U.S. and Canada and south to the Carolinas. However, it is rarely abundant at any sites and particularly rare in Texas. Strecker (1931) and Bachtel (1940) listed it from locations in the central and upper Trinity River and Strecker (1931) noted it in the lower Trinity River drainage as well, but there have been no apparent collections in the Trinity River drainage since. Strecker (1931)

also documented it and there is undated material in the UMMZ collection from the San Jacinto River, but there appears to be no recent confirmation of its presence in either the lower Trinity or San Jacinto rivers. Throughout its range, the AFS considers creeper to be vulnerable (Williams et al., in preparation) and in Texas, Howells (2009) recommended it be considered endangered.

**Lilliput (*Toxolasma parvus*):** Lilliput occurs from the Rio Grande north to southern Canada and east to Alabama. Historically there are multiple records of this species from the central and upper Trinity River basin, but no collections reported from the lower Trinity River or its associated waters. It has been noted at several sites within the San Jacinto River basin and was found recently dead in a pond adjacent to Spring Creek west of Lake Houston in 1999 (Howells 2000). This species likely occurs far more widely in ponds, canals, and oxbows in the lower Trinity and San Jacinto drainages that have not been surveyed. Additionally, historical reports often included Texas lilliput (*T. texasiensis*) and other lilliput species as forms of this lilliput, thus confounding interpretation of historical records and distribution. Throughout its range, the AFS considers this species to be stable (Williams et al., in preparation).

**Texas lilliput (*Toxolasma texasiensis*):** Texas lilliput ranges from the Rio Grande throughout much of Texas, east into Louisiana, and north in the Mississippi River Valley to southern Illinois. Living populations have been found at numerous sites in the upper and central Trinity and San Jacinto basins, with living Texas lilliput found in Mussel Shoal Creek in the lower Trinity River drainage in 1993 (Howells 1995). This species almost certainly occurs in many oxbows, pond, canals, and backwaters throughout the lower Trinity and San Jacinto rivers. However, there are no recent records of this species from the lower Trinity River itself. Many early records were undoubtedly listed as lilliput (*T. parvus*). Throughout its range, the AFS considers this species to be stable (Williams et al., in preparation).

**Fawnsfoot (*Truncilla donaciformis*):** This unionid occurs from the San Jacinto River north to Minnesota and Ohio and east to Alabama. Though occasionally common elsewhere, fawnsfoot is rather rare in Texas, the southwestern limit of its range (Howells 2009). There are a number of older records of collections in the upper and central Trinity River system and living fawnsfoot were found in the Trinity River upstream of Lake Livingston in 1996 (Howells 1997b). However, no records of it downstream of Lake Livingston were located during preparation of this report. Within the San Jacinto River basin, the USAO collection contains shells from the West Fork of the San Jacinto River taken in 1986 (USAO 3513) and H.D. Murray collected in the lower San Jacinto River about two decades earlier (Howells et al. 1996), but there do not appear to have been any subsequent reports of it from this drainage since. Throughout its range, the AFS considers it to be stable (Williams et al., in preparation). However, within Texas, Howells (2009) recommended it be considered threatened due to general scattered distribution and limited number of specimens and also due to the loss of the only significant population in the central Neches River in 2006-2008. Note that because of the rarity of both fawnsfoot and endemic Texas fawnsfoot (*Truncilla macrodon*) in Texas, several early workers confused these two unionids. Historical records of Texas fawnsfoot from the Trinity River drainage are misidentified fawnsfoot specimens; the extremely rare Texas fawnsfoot is confined to the Brazos and Colorado drainages of Central Texas.

**Deertoe (*Truncilla truncata*):** Deertoe occurs from the San Jacinto River north to Minnesota and the Great Lakes and east to Alabama. Within the upriver reaches of the Trinity River, deertoe has been found alive at a number of locations in recent years. Strecker (1931) reported it in the lower Trinity River drainage, but without subsequent confirmation of persisting populations since. Within the San Jacinto River basin, deertoe was found alive in Lake Houston in 2005 (Howells 2006). Throughout its range, the AFS considers deertoe to be stable (Williams et al., in preparation).

**Tapered pondhorn (*Unio merus declivis*):** This species occurs from the Rio Grande north and east through most of the major drainages in Texas, east to Alabama, and north to western Tennessee. It has been reported at several sites in the central and upper Trinity River drainage, found alive in Mussel Shoal Creek in 1993 (Howells 1995), but has not been found in the lower Trinity River or reported from the San Jacinto River basin. Although it would not necessarily be expected in the main channel of the lower Trinity River, tapered pondhorn is likely more abundant in ponds, oxbows, and canals in both the lower Trinity River drainage and in the San Jacinto River system than records indicate. Throughout its range, the AFS considers it to be stable (Williams et al., in preparation). NOTE: Many pondhorn mussels in Texas are morphologically intermediate between tapered pondhorn and pondhorn (*U.*

*tetralasmus*) and preliminary genetic studies have failed to clarify differences. As a result, actual collection and distribution records for both are badly confused.

**Pondhorn (*Unio merus tetralasmus*):** Pondhorn historically ranged from the lower Rio Grande drainage north and east through Texas, north to Illinois and Ohio and east to Alabama and northwestern Georgia. The species has been reported from a number of locations within the central and upper Trinity River drainage. The OSUM contains a specimen from the lower Trinity River drainage (OSUM 51698) and others from the East Fork of the San Jacinto River near Cleveland (OSUM 51720) both collected in 1922; the UMMZ includes others from the San Jacinto River drainage from that same year (UMMZ 29184, 73095), with an additional collection in a pond near Shepherd (USAO 5580, undated). Like other unionids from ponds and backwaters, this mussel is likely more common in the lower Trinity and San Jacinto basins than published reports and museum collections indicate. Throughout its range, the AFS considers pondhorn to be stable (Williams et al., in preparation). NOTE: Many pondhorn mussels in Texas are morphologically intermediate between pondhorn and tapered pondhorn (*U. declivis*) and preliminary genetic studies have failed to clarify differences. As a result, actual collection and distribution records for both are badly confused.

**Paper pondshell (*Utterbackia imbecillis*):** Paper pondshell occurs from the Rio Grande north to southern Canada and New York and east to Georgia. There are numerous records of paper pondshell from sites in the central and upper Trinity River basin. Strecker (1931) reported it in the lower Trinity River drainage. It is almost certainly present in many other ponds, canals, and oxbows, but would not be expected to be abundant in the main channel of the lower Trinity River. Within the San Jacinto River system, paper pondshell was found at a number of locations prior to 1989; here too, it is certainly present in other ponds and backwaters throughout the area that have not been surveyed. Throughout its range, the AFS considers this species to be stable (Williams et al., in preparation).

**Little spectaclecase (*Villosa lienosa*):** This unionid ranged from the San Jacinto River through waters in eastern Texas, north to the lower Ohio River drainage and east to Georgia. It has been reported from the central and upper Trinity River drainage by Strecker (1931) and Bachtel (1940), but not in recent years and no records from the lower Trinity River drainage were found during preparation of this report. Little spectaclecase was reported in the San Jacinto River drainage by Strecker (1931) and specimens from this area are present in several museum collections (UMMZ, USAO, OSUM) including the East and West forks, Lake Creek, Spring Creek, and the lower San Jacinto River; however, the last records of living specimens are from 1970. For reasons that are often unclear, this mussel appears to have been in decline in Texas waters over the past few decades. However, throughout its range, the AFS considers it to be stable (Williams et al., in preparation). Howells (2009) recommended it be considered threatened in Texas.

### Other Bivalve Mollusks from the Lower Trinity and San Jacinto Rivers

**Fingernail clams (Family Sphaeriidae):** This group has never been formally surveyed and studied in the lower Trinity and San Jacinto rivers. Statewide, four genera and 12 species have been reported. Species presence, abundance, and distribution remain unstudied and largely unknown, though none are known to be of conservation-status concern in Texas.

**Asian clam (*Corbicula fluminea*), Family Corbiculidae:** This exotic bivalve invaded eastern Texas in the 1950s and western Texas in the 1960s (Howells et al. 2004; Karatayev et al. 2005) and now occurs nearly statewide where permanent and semi-permanent waters are present to support it (Howells 2001c). Although this is an ecologically-undesirable exotic invader, it has become so well established that elimination is likely impossible. This exotic bivalve does not attach to solid objects, but reproduces rapidly and can attain very high densities. As a result, Asian clam has been known to clog cooling systems of power plants (including nuclear facilities) and other water transfer structures. Given that this mollusk cannot be eliminated, natural resource and water managers must operate and manage activities knowing that it is present and can be problematic.

**Dark falsemussel (*Mytilopsis leucophaeata*), Family Dreissenidae:** Dark falsemussel is native to the coastal estuaries of the Atlantic and Gulf coasts, including Texas (Howells et al. 1996). It may occur in fresh waters near the fresh-salt water interface, but certain minimal levels of salinity are required for successful reproduction. This species attaches to solid objects with adhesive byssal threads and has been accidentally transported to inland sites on boats moved from coastal areas. Dark falsemussel was probably not especially abundant in some Texas waters, but has been advantaged by shrimp-culture facilities constructed in coastal counties and may develop significant

densities under such conditions. Perhaps because it is native, dark false mussel has not been ecologically problematic in Texas, but it has been introduced in Europe and the U.S. West Coast where it can be a potential problem.

**Zebra mussel (*Dreissena polymorpha*), Family Dreissenidae:** Zebra mussel invaded the Great Lakes in the 1980s and has expanded its range in North America since. Zebra mussel and a related species, quagga mussel (*D. rostriformis bugensis*), have become major ecological problems in waters where they have become established. Although zebra mussel had been found on boats brought to Texas (Howells 2001c), none were documented in Texas waters until April 2009 when it was discovered in Lake Texoma, with several subsequent collections. In August 2009, it was also found in the waters associated with Lake Lavon in the upper Trinity River drainage. This exceptionally undesirable exotic invader has not been found in the waters of the lower Trinity or San Jacinto rivers to date. However, invasion downstream in both the Red and Trinity rivers can be expected.

**Atlantic rangia (*Rangia cuneata*), Family Mactridae:** Atlantic rangia is another estuarine species that can be abundant in coastal estuaries along both the Atlantic and Gulf coasts, including in Texas waters (Howells et al. 1996). It often occurs near the fresh-salt water interface and although it can survive for a time in fresh water, requires at least low levels of salinity for successful reproduction. Early collection by Native Americans that took it for food and more recently by modern man that used the species for fill material have both relocated this species numerous times and its shells can be found in some inland locations.

## MUSSEL SURVEY DATA LIMITATIONS

It should be recognized that a number of areas within the lower Trinity and San Jacinto drainages and their respective tributaries have not been surveyed, have not been examined in many years, or have not been studied by professional malacologists. Further, even areas that have been subjected to repeated mussel surveys may contain small pockets of micro-habitat that can contain limited numbers of unionids that have gone undetected.

Some stretches of the main channel of the Trinity River from a short distance below Mussel Shoal Creek through areas further downstream have not been surveyed. However, deep-shifting sands and collapsing banks in conjunction with general urbanization and other anthropogenic influences combine to produce undesirable freshwater mussel habitat that is unlikely to support large and diverse unionid assemblages. Published records and available museum collection data indicate the San Jacinto River downstream of Lake Houston has not been examined in several decades. But, here too, impact of urban and other development and habitat modifications are likely to have been unfavorable to freshwater mussels. The lower reaches of the East Fork of the San Jacinto River have not been surveyed, but could potentially contain freshwater mussel populations. However, limited numbers found in upstream areas of the East Fork San Jacinto River and dramatic reductions and elimination of populations once present in the West Fork San Jacinto River and Clear Creek suggest reason to question if abundant and diverse groups of unionids would still remain in the East Fork.

There are almost certainly ponds and oxbows within the lower Trinity and San Jacinto drainages that contain populations of freshwater mussels that are typical of pond and backwater habitats. However, none of the particularly rare unionids in southeastern Texas, including those proposed for state or federal listing, would be expected to maintain populations in such habitats. Some streams and bayous in the area that have yet to be surveyed could possibly still support limited assemblages of longer-lived mussel species. However, at this time, no such assemblages are known or expected within the planned Luce Bayou Interbasin Transfer Project area.

## LUCE BAYOU INTERBASIN TRANSFER PROJECT ASSOCIATIONS WITH FRESHWATER MUSSELS

Current data do not indicate significant freshwater mussel populations in the lower Trinity River downstream of Lake Livingston or along the route of Luce Bayou Interbasin Transfer Project that would experience significant direct impact from this project.

A noteworthy freshwater mussel assemblage is known to persist in the upper reaches of Lake Houston; however, it is not known to include any of the unionid species currently being considered for state or federal listing. Properly conducted Luce Bayou Interbasin Transfer Project construction efforts should have little or no negative impact on this assemblage of freshwater mussels. Indeed, input of Trinity River waters could actually be beneficial to those mussels in future times when the area might otherwise become dry. Given the significant water-filtration capabilities of freshwater mussels, continued secure survival of those in Lake Houston may actually contribute to improved water quality because of their presence.

### CAUTIONS AND CONSIDERATIONS

Impacts on freshwater mussels related to habitat alteration and construction activities typically occur at and downstream of the site where that activity was initiated. However, headcutting is one noteworthy exception (Hartfield 1993). Here removal of material from a stream bed can cause a collapse of the upriver side of the removal hole that cascades upstream until a dam, rock ledge, or other obstruction stops its progression and habitat destruction. Care needs to be taken at both the Trinity River water removal site and the East Fork San Jacinto River water release site to assure that headcutting does not occur.

Silt and sediment deposition from mining and development activities in the area have already had massive negative impacts on the San Jacinto River ecosystem. Despite this, a noteworthy freshwater mussel assemblage still persists in the upper reaches of Lake Houston. Efforts should be taken to prevent construction activities and waters transferred from the Trinity River from exacerbating this already degraded-habitat situation.

Some tributary streams, bayous, ponds, and oxbows do contain, or likely contain, at least limited populations of freshwater mussels. It would be wise to evaluate any association between water removal from the Trinity River and the associated water levels in these adjacent waters. Insufficient information was available to BioStudies as this report was being prepared to allow detailed comment herein.

Exotic bivalves in the lower Trinity River-San Jacinto River region could become problematic in the future. Asian clam invaded the area long ago. This species often flourishes in disturbed and modified habitats. In such situations, it often has major survival advantages over many native unionid mussels. Because Asian clam can reproduce rapidly, it has the potential to build large populations in only a few years. Water system operators of the Luce Bayou Interbasin Transfer Project need to be aware that dense accumulations of Asian clams could potentially clog equipment and water-transfer structures. Prevention of Asian clam is generally impractical, so periodic manual removal may be necessary. Additionally, zebra mussel was found to have invaded Lake Texoma in spring 2009. By summer 2009 it reached waters associated with Lake Lavon in the upper Trinity River drainage. This species too populates rapidly, but it attaches to solid objects with adhesive byssal threads and can seriously impact aquatic ecosystems in general and water-transfer equipment in specific. Its presence in Lake Lavon creates the opportunity for natural downstream movement in the Trinity River. If movement down the Trinity River occurs, and it is almost certain to happen, transfer of zebra mussel via the Luce Bayou Interbasin Transfer Project to the San Jacinto River system could be a possibility and could bring the species to the Houston metroplex. Little can be done to prevent natural dispersion of zebra mussel once it has invaded a system and attempting to manage it thereafter is often the only functional option.

Water transfer facilities have the ability to impinge larger fishes on intake screens and entrain fish eggs and larvae through the system. Given that all freshwater mussels in Texas require fish hosts to successfully reproduce, consideration should be given to system impact on fish populations with potential subsequent impact on local

unionids. For example, if buoyant eggs of freshwater drum were eliminated from a water body by a certain activity, bleufer (that depends exclusively on this fish) would eventually vanish from the system as well.

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**Table 1. Freshwater mussels reported from the Trinity and San Jacinto rivers and Buffalo Bayou in Texas, and their respective tributaries, including introduced (I) species.**

SPECIES		TRINITY	SAN JACINTO	BUFFALO
Common name	Scientific name	RIVER	RIVER	BAYOU
Threeridge	<i>Amblema plicata</i>	X	X	-
Flat floater	<i>Anodonta suborbiculata</i>	I	I	-
Rock-pocketbook	<i>Arcidens confragosus</i>	X	X	X
Tampico pearlymussel <sup>1</sup>	<i>Cyrtonaias tampicoensis</i>	I	-	-
Texas pigtoe	<i>Fusconaia askewi</i>	X	X	-
Wabash pigtoe <sup>2</sup>	<i>Fusconaia flava</i>	X	X	-
Round pearlshell	<i>Glebula rotundata</i>	X	X	X
Louisiana fatmucket	<i>Lampsilis hydiana</i>	X	X	-
Sandbank pocketbook	<i>Lampsilis satura</i>	X	X	-
Yellow sandshell	<i>Lampsilis teres</i>	X	X	X
White heelsplitter <sup>3</sup>	<i>Lasmigona complanata</i>	I	-	-
Fragile papershell	<i>Leptodea fragilis</i>	X	X	-
Pond mussel	<i>Ligumia subrostrata</i>	X	X	-
Washboard	<i>Megalanaia nervosa</i>	X	X	X
Threehorn wartyback	<i>Obliquaria reflexa</i>	X	-	-
Bankclimber	<i>Plectomerus dombeyanus</i>	X	X	-
Louisiana pigtoe	<i>Pleurobema riddellii</i>	X	X	-
Texas heelsplitter	<i>Potamilus amphichaenus</i>	X	-	-
Pink papershell <sup>4</sup>	<i>Potamilus ohioensis</i>	I	-	-
Bleufer	<i>Potamilus purpuratus</i>	X	X	-
Giant floater	<i>Pyganodon grandis</i>	X	X	X
Southern mapleleaf	<i>Quadrula apiculata</i>	X	X	X
Western pimpleback	<i>Quadrula mortoni</i>	X	X	X
Gulf mapleleaf	<i>Quadrula nobilis</i>	X	X	-
Pistolgrip	<i>Quadrula verrucosa</i>	X	X	-
Creeper (squawfoot)	<i>Strophitus undulatus</i>	X	X	-
Lilliput	<i>Toxolasma parvus</i>	X	X	?
Texas lilliput	<i>Toxolasma texasiensis</i>	X	X	X
Fawnsfoot	<i>Truncilla donaciformis</i>	X	X	-
Deertoe	<i>Truncilla truncata</i>	X	X	-
Tapered pondhorn	<i>Unio merus declivis</i>	X	X	X
Pondhorn	<i>Unio merus tetralasmus</i>	X	X	X
Paper pondshell	<i>Utterbackia imbecillis</i>	X	X	X
Little spectaclecase	<i>Villosa lienosa</i>	X	X	-
N species		33-34	28-29	11-12

<sup>1</sup> Unsuccessful introductions of this species have been reported in the upper Trinity River (Howells et al. 1996) and near the mouth (Howells and Tirpak 2003), but it is not known to be established in the system.

<sup>2</sup> Reports of this species are problematic due to confusion with Texas pigtoe and there has been no genetic confirmation to date that specimens from Texas waters are definitely Wabash pigtoe.

<sup>3</sup> Neck (1990) and Howells et al. (1996) reported this species in the upper Trinity River drainage, but the introduction was apparently unsuccessful.

<sup>4</sup> Pink papershell appeared in the upper Trinity River drainage some years ago in areas typically inhabited by Texas heelsplitter, a closely related sister species. Since then, most specimens in the upper Trinity more closely resemble pink papershell or intermediates and no genetic studies have been conducted to date to confirm the true identity of these specimens. Specimens found in recent years in Lake Livingston and the Trinity River immediately upstream of that impoundment still appear morphologically like typical Texas heelsplitter.

Table 2. Freshwater mussels reported from the lower Trinity River downstream of Lake Livingston, tributaries of the Trinity River downstream of Lake Livingston, the East and West Forks of the San Jacinto River and their tributaries, Lake Houston, and San Jacinto River downstream of Lake Houston, Texas, including available collection records (Total) and living and recently dead specimens documented since 1991 (Recent).

SPECIES Common name	LOWER TRINITY RIVER			LOWER TRINITY TRIBUTARIES			West Branch			Lake Houston			East Branch			Below L. Houston		
	Total	Recent		Total	Recent		Total	Recent		Total	Recent		Total	Recent		Total	Recent	
Threeridge	X	-		X	-		X	-		X	-		X	-		X	-	
Flat floater	-	-		I	-		I	-		I	-		-	-		-	-	
Rock-pocketbook	-	-		X	X		X	-		-	-		-	-		X	-	
Tampico pearlymussel	-	-		I	-		-	-		-	-		-	-		-	-	
Texas pigtoe	X	-		X	-		-	X		-	-		X	-		X	-	
Wabash pigtoe	?	-		?	-		?	-		-	-		?	-		?	-	
Round pearlshell	X	-		-	-		X	-		-	-		-	-		X	-	
Louisiana fatmucket	X	X		X	X		X	-		X	-		X	-		X	-	
Sandbank pocketbook	-	-		-	-		X	-		-	-		-	-		X	-	
Yellow sandshell	X	-		X	X		X	X		X	X		X	X		X	X	
Fragile papershell	X	-		X	X		X	X		X	X		X	X		X	X	
Pond mussel	-	-		X	-		X	X		-	-		-	-		X	-	
Washboard	X	-		-	X		-	-		X	-		X	-		-	-	
Threehorn wartyback	X	X		X	-		-	-		-	-		-	-		-	-	
Bankclimber	X	-		X	X		X	-		X	-		X	-		X	-	
Louisiana pigtoe	-	-		-	-		X	-		-	-		-	-		-	-	
Texas heelsplitter	X	-		-	-		X	-		-	-		X	-		X	-	
Bleufer	X	-		-	-		-	-		-	-		-	-		-	-	
Giant floater	-	-		X	X		X	X		X	X		X	X		X	X	
Southern mapleleaf	X	X		X	X		X	X		X	X		X	X		X	X	
Western pimpleback	X	-		X	X		X	X		X	X		X	X		X	X	
Gulf mapleleaf	X	X		X	X		X	X		X	X		X	X		X	X	
Pistolgrip	X	-		X	-		-	-		-	-		-	-		-	-	
Creepers (squawfoot)	-	-		X	-		-	-		-	-		-	-		-	-	
Lilliput	-	-		-	-		-	-		-	-		-	-		-	-	
Texas lilliput	-	-		X	X		X	X		-	-		-	-		X	X	
Fawnsfoot	-	-		-	-		X	-		-	-		-	-		X	-	
Deertoe	-	-		X	-		X	-		-	-		-	-		X	-	
Tapered pondhorn	-	-		X	X		-	-		-	-		-	-		-	-	
Pondhorn	-	-		X	-		-	-		-	-		-	-		-	-	
Paper pondshell	-	-		X	-		-	-		-	-		-	-		-	-	
Little spectaclecase	-	-		X	-		X	-		-	-		-	-		X	-	
N species reported	15-16	4		24-25	12		23	11-12		12	9		17	1		22	0	

# Freshwater Mussel Survey Field Summary Report

Prepared by

AECOM

Prepared for

Luce Bayou Interbasin Transfer Project

January 2012

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  - Freshwater Mussel Survey Area and Habitat Characterization Maps
  - Freshwater Mussels of Texas Distribution Chart

## 1.0 Introduction

The purpose of this report is to provide the results of the benthic habitat and mussel characterization efforts completed in support of the proposed Luce Bayou Interbasin Transfer Project (LBITP). This survey was performed by AECOM with logistical assistance provided by the Coastal Water Authority. the mussel surveys were performed in the Trinity River at the proposed Capers Ridge Pump Station location (Trinity River) and in the East Fork of the San Jacinto River at the proposed Lake Houston discharge structure (Lake Houston) (**Figure 1**). This report summarizes the results of these habitat and mussel characterizations which were conducted in a manner consistent with those described in the LBITP Qualitative Freshwater Mussel Survey Scope of Work (**Attachment A**) and similar surveys previously conducted in East Texas by Karatayev and Burlakova (2007).

The freshwater mussel surveys were undertaken to assess the abundance and diversity of mussel species present within the Trinity River and Lake Houston adjacent to the proposed LBITP pump intake or canal discharge locations. The U.S. Fish and Wildlife Service (USFWS) was interested in determining whether currently listed threatened and/or endangered freshwater mussel species in Texas or those species that may be proposed for listing by the USFWS were present in the area of the proposed LBITP facilities (**Attachment A**). Habitat and water quality data were also collected at each survey location to explain habitat preferences for the mussel species identified. Although previous efforts by the Texas Park and Wildlife Department (TPWD) in the Lake Houston watershed have documented dense mussel assemblages, existing mussel population data on the main stem of the Trinity River are lacking; based on the results of past studies, freshwater mussels have been identified in areas restricted to backwaters and tributaries of the Trinity River. The data collected as part of this survey will be used to supplement existing freshwater mussel survey data and represent a high resolution, although geographical localized, survey within the Trinity River and Lake Houston.

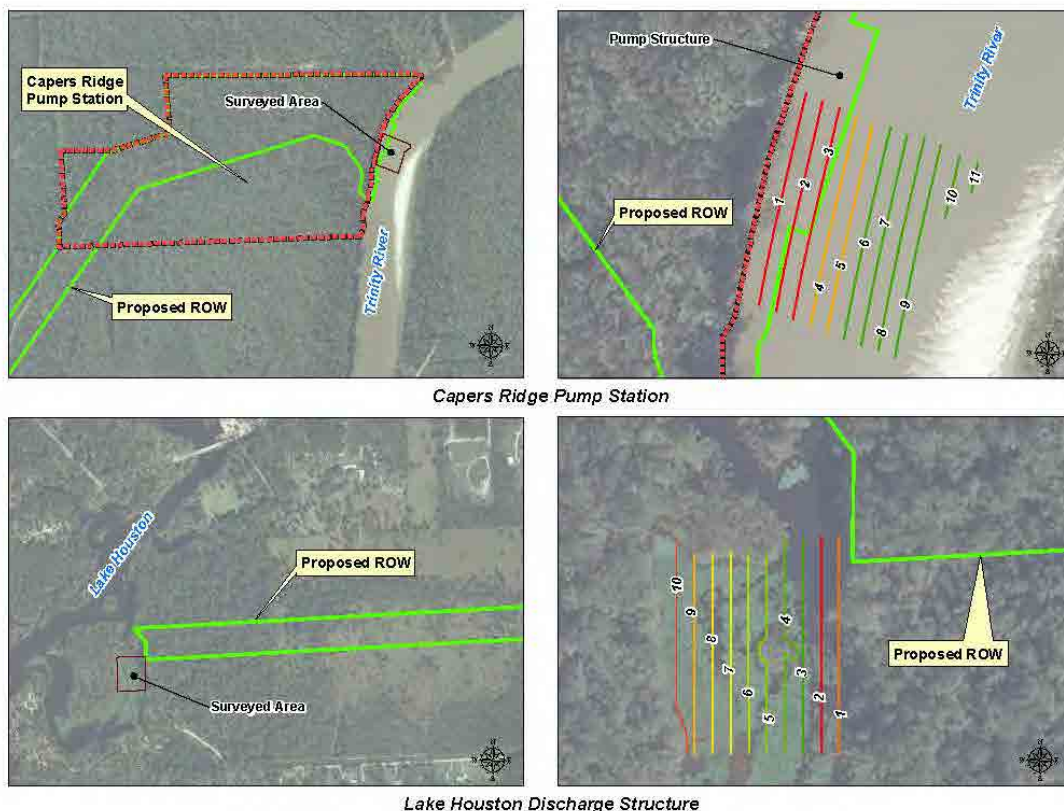


Figure 1 - Intake and Discharge Mussel Survey Locations

## 2.0 Methods

Methods for characterizing habitat and mussel populations and collection of water quality data were generally consistent between the Lake Houston and Trinity River survey locations. The one exception was the higher frequency in which wader-based survey techniques were required at the Lake Houston discharge location compared to the Trinity River intake location due to the low water levels encountered at Lake Houston.

### 2.1 Mussel and Habitat

Prior to field deployment, a series of transects were established to encompass representative habitats downstream of the proposed Trinity River intake and Lake Houston discharge locations (**Figure 1**).

Transects were spaced 25 feet (ft) apart in each location, encompassed the entire river width based on available aerial photography, and were oriented parallel to prevailing water flow in both areas. The majority of transects in both areas measured approximately 300 feet in length although shorter transects were required in some areas to accommodate or avoid the exposed shoreline as identified from aerial photography (**Attachment A** and **Figure 1**). While the number and length of individual transects in each area varied, the transect configuration in both locations was developed to confidently survey mussel populations and characterize habitat in an area totaling at least 16,000 ft<sup>2</sup>. To determine if mussel abundance and diversity varies with water depths, transects were established using 6 ft water depths determined from the historical average river depth from nearby gauge data.

Transects were determined using handheld GPS device capable of 3 feet accuracy (**Figure 2**). Based on water depths encountered, surveys along each transect were completed by either wading in the river or using an experienced dive team to collect freshwater mussel data using the methodology approved by the TPWD (**Figure 3** and **Figure 4**). The area extending 3 feet on both sides of each transect was inspected for the presence of live and dead freshwater mussels. While wader-based techniques integrated both visual and physical cues to detect mussels along transects in the shallow water regions, divers searched for organisms by using hand searches, as visual inspections were precluded due to poor visibility at both the Trinity



**Figure 2. Setting Transects at Lake Houston**



**Figure 3. Diver-Based Surveys at Lake Houston**



**Figure 4. Wader-Based Surveys at Lake Houston**

River and Lake Houston locations. Survey data collected included observations related to the presence of submerged aquatic vegetation (SAV) and descriptions and conditions of the bottom, bank, and substrate.

Live mussel and mussel shells encountered along each 100 ft transect were placed into collection bags and held in ambient river water prior to identification. While mussel shells representing dead individuals observed along transect were collected, this data collection effort was limited to shell fragments that would allow confident identification of the species type during data analyses. Identification of live and dead mussel specimens included speciation to the lowest taxonomic group possible based on existing mussel identification reports (Howells et. al. 1996), shell measurements, and observations made of the condition of each shell (**Figure 5**). While live specimens were returned to the area in which they were collected, shells of dead specimens were retained and can be made available upon request.



**Figure 5. Mussel Identification at Trinity River**

Habitat characterizations were conducted along each 100 ft transect surveyed and included a general description of SAV presence/absence, SAV percent cover, and dominant substrate type. Representative photographs of the mussel species collected and site conditions at the time of the surveys were collected at the Trinity River and Lake Houston locations.

## **2.2 Water Quality**

Freshwater mussels in Texas occur in rivers and streams, reservoirs, ponds, and canals and in surface water with still to moderate flow conditions. They can occur on a variety of substrate types, but most frequently are found on firm mud, stable sand and gravel or a combination of these substrate types. Unionids may occur in relatively shallow water to water of many meters in depth, providing dissolved oxygen is present at sufficient concentrations to avoid hypoxia conditions (low oxygen conditions  $< 2 \text{ mg l}^{-1}$ ), a limitation that many reservoirs in summer do not continuously meet. Many mussels tolerate a wide range of water temperature as long as high or low extremes are not encountered and annual fluctuations support normal breeding activity. Most species do not tolerate acidic water (calcium  $\text{Ca}^{2+}$  levels lower than  $12 \text{ mg/l}$  and pH below 7.3), long term water temperatures more than  $32^{\circ}\text{C}$  or salinity especially greater than 8 parts per thousand (ppt) (Strayer 1991; Howells 1995; Whittier *et al* 1995).

Unionids usually require environments that are very stable over long periods of time. Generally freshwater mussels are extremely intolerant of changes to their environments including to the terrestrial environment. Mussels cannot tolerate salinity or long-term drawdown caused by drought conditions. Water quality profiles were collected following mussel and habitat surveys. These data were collected using a calibrated YSI handheld device capable of measuring temperature, pH, dissolved oxygen, and conductivity. Point measurements were recorded at the sediment water interface (bottom), middle water column, and below the water surface.

## 3.0 Results

Freshwater mussel survey results are discussed below by geographic location since both survey areas are unique with respect to surface morphology, sediment deposition, water depth, type of aquatic ecosystem, water currents and flow conditions, water depths, substrates types, and related conditions that may affect or influence freshwater mussel populations.

### 3.1 Trinity River (Intake Location)

The freshwater mussel survey along the area of the Capers Ridge Pump Station location in the Trinity River was conducted on January 6, 2012, during a period of historically low water levels, which made access to the site and subsequent survey efforts difficult. According to the National Weather Service (NWS 2012), since 2008, Texas has been experiencing a rainfall deficit with this deficit being identified as severe in 2010. Drought conditions continued in 2011, and the spring, summer and fall months were some of the driest on record in this part of Texas. Large portions of the river along the western shoreline were shallow especially compared with historic river data and a great number of transects surveyed using wader-based techniques (**Figure 6**).



**Figure 6. Trinity River Survey Area**

While the majority of transects 8 through 10 were located in ankle deep water, transect 11 near the point bar in the background of **Figure 6** was completely exposed. The shallow water condition for these transects permitted extremely detailed inspections of the river bottom and banks. These detailed surveys provided an opportunity to substantiate the results of the diver-based mussel survey conducted as the results of the freshwater mussel survey were consistent using either survey methods.

A total of 11 transects that collectively measured 2,840 linear feet were established across the Trinity River opposite and slightly downstream of the proposed pump locations at the LBITP intake structure. The survey area included three feet on each side of these 11 transects; the total area surveyed was approximately 17,040 ft<sup>2</sup>.

#### 3.1.1 Mussel and Habitat

Substrates in the Trinity River survey area were generally homogenous with little variability observed between upstream and downstream regions. Hard substrates were composed of primarily packed silts intermixed with fine grain sand with very little bottom relief beyond the occasional small piece of coarse woody debris. However, the river bank in the area is unstable and the shifting-sand bottoms encountered during the survey are unacceptable mussel habitat (Howells 2009).

The area surrounding the transects established in the deepest portions of the Trinity River along the western shoreline were found to contain small and medium gravel substrates; however these substrates were limited in extent and this substrate type represents less than 10 percent of the total area surveyed. Limited areas of



**Figure 7. Juvenile Giant Floater Shells Collected From the Trinity River**

gravel were observed to be present beneath areas of unconsolidated silt and fine sands. These silts and fine sands are easily disturbed and re-suspended in the water column. Fine silts and sands impact mussel species by clogging gills or preventing the presence of necessary host fishes (Howells 2009).

One individual SAV plant species was found along transect 1. The current in the river at this location was notable and the substrate was easily suspended. The suspended sediment reduced visibility during the survey to approximately one foot.

In the shallow water areas along the Trinity River, the freshwater mussel survey was necessarily conducted by hand. While only one live mussel, a juvenile giant floater (*Pyganodon grandis*), was encountered on transect 10, mussel shells were collected from transects 3, 8, and 9. The majority of mussels identified by shell type were juvenile giant floaters located primarily along the shallow transects 8 through 10 (**Figure 7**), the shell of a southern mapleleaf (*Quadrula apiculata*) was collected from the middle of transect 3 (**Figure 8**). Both of these species are commonly found in East Texas (Howells, *et al.*, 1996). **Table 1** summarizes data collected.



**Figure 8. Juvenile Southern Mapleleaf Shell Collected From the**

As discussed above, freshwater mussel species or specimens identified at the Trinity River intake location were not extensive; one live juvenile giant floater specimen was identified. These juvenile giant floaters may have been deposited on exposed shallow banks after drifting on the current from the upstream reach of the river. The southern mapleleaf shell is relatively heavy and thick and these characteristics likely caused the shell to be deposited and identified from the area of the river with a deeper water depth.

**Table 1. Habitat and Mussel Characterization in the Trinity River Intake Area**

<b>Transect</b> (Exposed (E)/ Submerged (S))	<b>Substrate*</b>	<b>Vegetation</b> (% Cover)	<b>Mussel</b> <b>Species**</b> (North (N) Middle (M) South (S))	<b>Mussel Length</b> (mm)	<b>Mussel or</b> <b>Shell</b> <b>Condition</b>
1 (S)	S, Sa	Y (<1% SAV)	NA	NA	NA
2 (S)	S, Sa, G	N	NA	NA	NA
3 (S)	S, Sa	N	SM (N)	36	Fresh
4 (S)	S, Sa	N	NA	NA	NA
5 (S)	S, Sa	N	NA	NA	NA
6 (S)	S, Sa	N	NA	NA	NA
7 (S)	S, Sa	N	NA	NA	NA
8 (S)	S, Sa	N	7 GF (M)	21,19,17,17,15,16,13	Fresh
9 (E/S)	S, Sa	Y (20% RFW)	9 GF (M)	14,17,16,18,18,15,17,19,15	Fresh
10 (E)	S, Sa	Y (40% RFW)	GF (N)	18	Alive
11 (E)	S, Sa	Y (40% RFW)	GF (N)	19	Fresh

\*C=Clay, S=Silt, Sa=Sand, G=Gravel

\*\* GF= Giant Floater, SM = Southern Mapleleaf

NA = Not Applicable

### **3.1.2 Water Quality**

During the first day of the Trinity River survey, equipment malfunction prevented the collection of water quality data with the YSI multi-probe device. Due to the difficulty of accessing the water at the proposed Capers Ridge Pump Station, an additional field trip to collect water quality data was planned for January 9, 2012. On the date planned for an additional attempt to collect water quality data in the survey area, severe thunderstorms moved through the area and produced large amounts of rainfall. The weather conditions precluded water quality data collection at the Trinity River due to health and safety concerns. According to the Trinity River Authority (HCOEM 2012), 4.77 inches of rainfall was measured at the Lake Livingston Dam, which is approximately 50 miles north of the proposed Capers Ridge Pump Station property. As a result, representative water quality data for the Trinity River survey were not collected and are not available for analysis or review. However, Espey Consultants have collected water quality data in the vicinity of the project and this report will be updated as these data become available.

## **3.2 Lake Houston (Discharge Location)**

The freshwater mussel and water quality surveys at the Lake Houston discharge location for the LBITP were conducted on January 4, 2012. The Lake Houston reservoir has also experienced historically low water levels due to drought conditions present in 2010 and 2011. Recent rainfall has mitigated these effects somewhat although conditions can be considered not typical.

According to Coastal Water Authority personnel who operate the Lake Houston reservoir, as an observed consequence of the drought, the majority of the proposed LBITP discharge survey area has been completely exposed for many months. As a result, it appears as though dense terrestrial riverine fringing wetland (RFW) vegetation has migrated in the direction of Lake Houston to inhabit areas that are typically submerged by water. To compensate for existing conditions, the freshwater mussel surveys in shallow water areas were performed using wader methods of data collection. The mussel transects established at the canted Lake Houston discharge location and the extreme southern and northern portions of transects 8 through 10 were shallow and were therefore surveyed using wader-based techniques of data collection. The shallow conditions allowed extremely detailed inspections of lake conditions in some areas. These detailed surveys provided an opportunity to substantiate the results of the diver-based mussel survey conducted as the results of the freshwater mussel surveys were consistent using either survey methods.

A total of 10 transects that collectively measured 3,040 linear feet were established within Lake Houston opposite and canted downstream of the proposed discharge location of the LBITP. The survey area included three feet on each side of these 10 transects; the total area surveyed was approximately 18,240 ft<sup>2</sup>.

### **3.2.1 Mussel and Habitat**

With little exception, substrates in the Lake Houston survey area were almost completely covered with riverine fringe wetland (RFW) vegetation exposed during water level changes associated with drought conditions. This vegetation was in poor condition and was decaying. Transect 2 was the only area in which dense, decaying RFW vegetation overlying the lake bottom was not observed. This area was the deepest portion surveyed and the lack of RFW vegetation implies it remained partially inundated during drought conditions.

The underlying substrate along all transects was composed of extremely hard packed clays and silts with numerous large drainage fissures indicative of periods of extended desiccation and erosion. In addition, coarse woody debris was frequently present within all areas surveyed. Minimal water movement in the area and the ease of sediment suspension caused poor visibility for the diver-based survey.



**Figure 9. Giant Floater Shells Collected From Lake Houston**

Similar to the Trinity River, conditions present in Lake Houston permitted comprehensive freshwater mussel surveys (**Table 2**). No live mussel specimens were encountered in this area; however, shells were collected along each transect with the exception of transects 1, 4, 5, and 8. The majority of 14 dead mussel shells collected were adult giant floaters (**Figure 9**), although shells of 2 individual southern mapleleaf mussels were collected from the middle and northern sections of transect 2 and 7, respectively (**Figure 10**). Both of these mussel species are commonly found in East Texas freshwater systems. The majority of the mussel shells were located from the relatively deeper portions of the survey area.

Unacceptable mussel habitat conditions exist in the survey area and include conditions of dewatering caused by drought that exposes mussels to temperature extremes and fluctuating water levels, the presence of

decaying herbaceous riverine fringe wetlands that prevent digging into the substrate, reduce phytoplankton food sources or confound movement, or cause lack of host fishes.



**Figure 10. Southern Mapleleaf Shells Collected From Lake Houston**

**Table 2. Habitat and Mussel Characterization in the Lake Houston Discharge Area**

<b>Transect</b> (Exposed (E)/ Submerged (S))	<b>Substrate*</b>	<b>Vegetation Present (% Cover)</b>	<b>Mussel Species** (North (N), Middle (M), South (S))</b>	<b>Length (mm)</b>	<b>Mussel or Shell Condition</b>
1 (S)	C	Y (100% RFW)	NA	NA	NA
2 (S)	C	N	SM, GF, GF (N)	74, 102, 132	Fresh
3 (S)	C	Y (100% RFW)	GF (N); GF (M)	124; 98	Weathered
4 (S)	C	Y (100% RFW)	NA	NA	NA
5 (S)	C	Y (100% RFW)	NA	NA	NA
6 (S)	C	Y (100% RFW)	GF (M)	118	Subfossil
7 (S)	C	Y (100% RFW)	SM (N)	38	Weathered
8 (S)	C	Y (100% RFW)	NA	NA	NA
9 (S)	C	Y (100% RFW)	GF (N); GF, GF (S)	116; 118, 122	Weathered
10 (S)	C	Y (100% RFW)	GF, GF (M)	115, 110	Subfossil

\*C=Clay, S=Silt, Sa=Sand, G=Gravel

\*\* GF= Giant Floater, SM = Southern Mapleleaf

NA = Not Applicable

### 3.2.2 Water Quality

Water quality data were collected in a relatively deep section of the Lake Houston survey area between the northern portions of transects 7 and 8 in order to represent a profile in the survey area. While water temperature and dissolved oxygen levels decreased with depth, pH levels at the sediment water interface were higher than those in the surface waters. Little variability in conductivity with depth was observed. Additional detail regarding water quality data collected is presented in **Table 3**.

**Table 3. Water Quality in the Lake Houston Discharge Area**

Depth	Temperature (°C)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	pH
Bottom (0ft)	11.01	0.072	2.61	7.23
Middle (-2ft)	11.75	0.072	3.01	6.88
Surface (-4ft)	12.97	0.078	3.12	6.82

## 4.0 Discussion and Findings

The purpose of the freshwater mussel survey is to assess the presence or absence of freshwater mussel species in the vicinity of the intake and discharge locations of the proposed LBITP. The intake location of the LBITP at Capers Ridge is located within the lower Trinity River at river mile (RM) 65, downstream of Lake Livingston and upstream of Liberty, Texas. The location of the proposed LBITP discharge is near the confluence of the East Fork of the San Jacinto River and Lake Houston in the vicinity of Huffman, Texas. The protocols for the qualitative freshwater mussel survey were reviewed and approved prior to the field investigation by the Texas Parks and Wildlife Department (Dr. Amy Turner TPWD 2011). An aquatic species collection permit was also issued by TPWD.

No Federal- or State-listed threatened and/or endangered, rare, invasive, or potential candidate species of freshwater mussels were identified based on the results of the mussel survey conducted. Unlike some organisms that leave little trace of their presence, freshwater mussels and other bivalve mollusks often leave shells, valves, or fragments as evidence of their past presence. Fresh, weathered and subfossil mussel shells of juvenile and giant floater mussels, two fresh and weathered shells of the southern mapleleaf mussel, and one live juvenile giant floater mussel collected from the Trinity River were identified. Similar to earlier reports (Howells 2009), current data and survey results do not indicate notable freshwater mussel populations in the lower Trinity River downstream of Lake Livingston or at the discharge location of the LBITP. Neither of the aquatic habitats of the lower Trinity River and the East Fork of the San Jacinto River near the confluence with Lake Houston appear to be acceptable to support freshwater mussel species and there is no evidence to suggest that large assemblages of mussel species or that rare species would be present (Howells 2009). Extremely low densities of freshwater mussels were identified based on the quantitative freshwater mussel survey conducted. Habitat constraints for freshwater mussels including an unstable environment, shifting sands and silts, decaying vegetative cover (Lake Houston), collapsing or unstable river or stream banks, extreme water level fluctuations or temperature fluctuations resulting from long periods of exposure, and other anthropogenic influences create conditions that are undesirable for freshwater mussels. The conclusion based on the survey conducted is that the aquatic habitat in the vicinity of the LBITP is unlikely to support large, diverse or rare unionid populations although it is possible that areas of the lower Trinity River may contain small pockets of micro-habitat that could support limited numbers of freshwater mussels (Howells 2009).

## 5.0 References

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## **ATTACHMENT A**

## **Scope of Work**

### **Qualitative Survey of of Freshwater Mussels (LBITP)**

**Background:** Unionid mussels are an integral part of freshwater ecosystems and have been recognized as reliable indicators of environmental quality due to their sensitivity to natural occurring and anthropogenic habitat and water quality impacts. Species specific mussel abundance and distribution are primarily influenced by hydrology and benthic habitat and usually prefer moderate to swiftly flowing waters. As a result, mussel populations are highly sensitive to instream flow modification and subsequent scour and deposition. Because of their relative sensitivity and inability to rapidly respond and avoid adverse conditions, over one-half of the approximately 300 species in North America are currently extinct, endangered, or threatened. Although the Texas Parks and Wildlife Department (TPWD) initiated statewide abundance and distribution surveys in January 1992, the existing data for freshwater mussels in Texas is limited. As mentioned, the status of individual mussel populations is sensitive and can fluctuate over small temporal and spatial scales; therefore it is critical to periodically reassess areas capable of supporting freshwater mussels to confirm existing population conditions. Discussions with USFWS suggest a species specific qualitative (presence/absence) mussel survey be conducted at the following locations: the proposed intake (Capers Ridge Pump Station) on the Trinity River, just downstream of the pump station, and at the discharge point located on the East Fork of the San Jacinto River which drains into Lake Houston (Exhibit 1). Existing mussel population data on the mainstem of the Trinity River is lacking and has historically been restricted to the backwaters and tributaries. Conversely, data in Lake Houston immediate watershed indicates the presence of diverse mussel communities but is antiquated and not specific to areas encompassed by this project. Given the limited information available on Texas freshwater mussels in the project area, the proposed surveys will generate useful inventory data for both common and any threatened and endangered mussel species which inhabit these two areas for future use by managers, researchers, and decision makers.

#### **Task 1: Collect mussel distribution, habitat utilization, and related data in the Trinity and San Jacinto River Basins**

Through coordination between USFWS and TPWD mussel surveys will be conducted at predetermined locations on the Trinity River downstream of the Capers Ridge Pump Station and at the outfall location on the East Fork San Jacinto River (Lake Houston). The extent of the survey area will also be coordinated with USFWS and TPWD and is anticipated to encompass the entire river width extending 100 meters downstream from the Capers Ridge Pump Station and approximately 5,000 m<sup>2</sup> surrounding the discharge point at the East Fork San Jacinto River. Survey methodology will be consistent with those described in the East Texas Mussel Survey (Karatayev and Burlakova, 2007).

Task 1 includes depth stratified surveys (e.g. riffle, run, pool) at both locations. The level of effort within each depth strata will be proportional to the acreage of the various depth strata available in the agreed upon survey area in each location. Within each area, a combination of transect and quadrat surveys will be conducted to determine the species specific abundance of mussels present. Transect and quadrat locations will be generated prior to field surveys and will be deployed in the field using a handheld GPS. It is anticipated that transects will be spaced 25 feet apart parallel to the flow and a minimum of 30 quadrats will be surveyed along the transects although this spacing may be modified based on water depth and visibility. The methodology for assessing mussel populations within each transect and quadrat will be based on water depth and visibility and is anticipated to include some combination of wading, snorkeling, and scientific diver surveys.

Within each transect, mussels (dead or alive) encountered will be speciated (if feasible) and returned to their original location. Within each transect, a predefined number of 1m<sup>2</sup> quadrat samples will be collected to assess mussel density. Mussels unable to be identified to species level in the field will be retained temporarily for further analysis. In the event that large quantities of common species are found, an adaptive sampling program will be implemented to sub sample these locations and estimate abundance and density. Threatened and endangered species are not assumed to be found in large quantities therefore it is expected that sub sampling will not be undertaken, and rather all listed species will be counted. Additional data collected within transects will include an assessment of vegetation present, dominant substrates, and other general ecological observations. Dominant substrates will be categorized visually using a modified Wentworth scale. At a representative location within each depth strata at both areas, water temperature, pH, dissolved oxygen, and water conductivity/salinity point measurements will be recorded at the water sediment interface using a calibrated YSI handheld device as water visibility permits, representative photographs of habitat present within each depth strata will be taken. Additional photographs will be taken to inventory mussel species collected. Sampling will be conducted in consultation with the, USFWS and TPWD. A representative from each agency will be notified prior to field sampling events to allow their participation, if desired. Field scientists responsible for mussel speciation will be properly trained and equipped with field guides to properly identify the mussel species with the potential to inhabit the Lake Houston and Trinity River. These include but are not limited to the species identified in the Freshwater Mussels of Texas Distribution Chart (Attachment A).

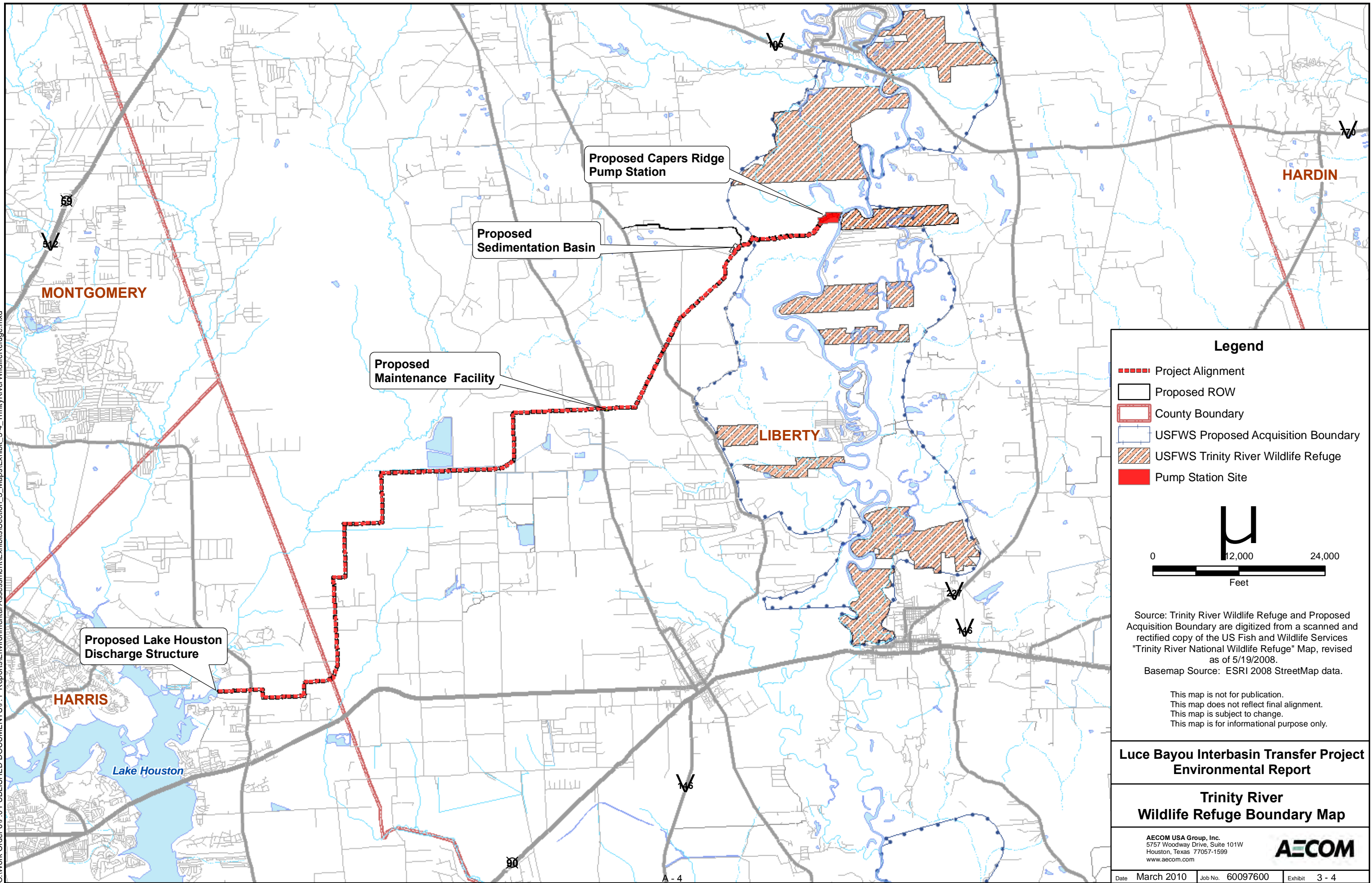
## **Task 2: Identify mussels, prepare species lists, and report data**

Staff will identify unionids collected in the field when feasible, or preserved and taken back to conduct identifications in the office if they are not listed species. To confirm mussel identification, a small number of representative specimens and/or detailed photographs may be retained and sent to taxonomic experts in mollusks identification at TPWD if desired. At least one individual of each species collected from a sample site will be appropriately vouchered (preserved or adequately photographed). TPWD staff may provide assistance and quality assurance as necessary. A brief report summarizing the results of will be submitted to the appropriate agencies. This report will include a brief narrative explaining the trends in mussel communities observed and also a summary of species specific mussel abundance by habitat in Microsoft Excel format. If warranted, abundance maps will be generated indicating the location (GPS coordinates included) of any threatened and endangered mussel species encountered. Photographs will be submitted in a suitable electronic format, along with metadata providing GPS coordinates, habitat notes, and sampling time/location information.

## **References**

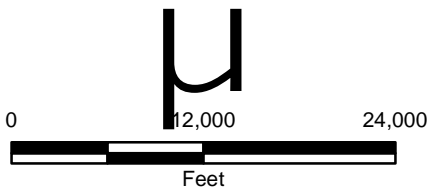
Kuratayev, A. Y. and L. E. Burlakova. 2007. Final Report-State Wildlife Grants Program. East Texas Mussel Survey.

O:\Work Order 617.0 PUBLISHED DOCUMENTS\7.1 Reports\Environmental Assessment\Exhibits\Section 3 - Maps\Exhibit 3-4 Trinity River Wildlife Refuge.mxd



### Legend

- Project Alignment
- Proposed ROW
- County Boundary
- USFWS Proposed Acquisition Boundary
- USFWS Trinity River Wildlife Refuge
- Pump Station Site



Source: Trinity River Wildlife Refuge and Proposed Acquisition Boundary are digitized from a scanned and rectified copy of the US Fish and Wildlife Services "Trinity River National Wildlife Refuge" Map, revised as of 5/19/2008.  
Basemap Source: ESRI 2008 StreetMap data.

This map is not for publication.  
This map does not reflect final alignment.  
This map is subject to change.  
This map is for informational purpose only.

### Luce Bayou Interbasin Transfer Project Environmental Report

### Trinity River Wildlife Refuge Boundary Map

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Houston, Texas 77057-1599  
www.aecom.com

**AECOM**

## Freshwater Mussels of Texas Distribution Chart

This list is intended to serve as a starting point to familiarize yourself with mussel species that may occur in your area. Not all species indicated may still occur within the basin, and some species have very limited distributions within a system. Some species, in addition to those indicated, may occur in your river system. Note species lists for adjacent systems to familiarize yourself with other possible species. Some river systems, such as the Llano, Pedernales, and San Saba, appear to have few or no living mussel populations.

Page	Family: Unionidae	1. Canadian River	2. Wichita River	3. Red River	4. Sulphur River	5. Big Cypress Bayou	6. Sabine River	7. Angelina River	8. Neches River	9. Trinity River	10. San Jacinto River	11. Brazos River	12. Little Brazos River	13. Navasota River	14. Colorado River	15. Concho River	16. San Saba River	17. Llano River	18. Pedernales River	19. San Marcos River	20. Guadalupe River	21. San Antonio River	22. Frio River	23. Nueces River	24. Rio Grande River	25. Devils River	26. Pecos River	27. Lavaca River
1	<i>Amblema plicata</i> (three-ridge)			X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	X	X	X	O	X				
2	<i>Anodonta suborbiculata</i> (flat floater)			*		*	*	*	*	*	*	*																
3	<i>Arcidens confragosus</i> (rock pocketbook) <sup>6</sup> (TWAP - SC)			X	X	X	X	X	X	X	X	X	X		X					X	X							X
4	<i>Arkansia wheeleri</i> (Ouachita rock-pocketbook) <sup>1</sup> (TWAP - FE)			X																								
5	<i>Cyrtonaias tampicoensis</i> (Tampico pearlymussel)			I						I		X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X
6	<i>Elliptio dilatata</i> (spike)																			O								
7	<i>Fusconaia askewi</i> (Texas pigtoe) <sup>2,3,8</sup> (TWAP - SC)				X	X	X	O	X	X	X																	
8	<i>Fusconaia flava</i> (Wabash pigtoe) <sup>6</sup>			X	X	X	O	X	X	X	X																	
9	<i>Fusconaia lananensis</i> (triangle pigtoe) <sup>2,8</sup> (TWAP - SC)								X	X																		
10	<i>Glebulia rotundata</i> (round pearlshell)					X		X	X	X	X										O	X						X
11	<i>Lampsilis bracteata</i> (Texas fatmucket) <sup>6,8</sup> (TWAP - SC)											O			X	X	X	O	O	X	X	X						
12	<i>Lampsilis cardium</i> (plain pocketbook) <sup>9</sup>			X		X																						
13	<i>Lampsilis hydiana</i> (Louisiana fatmucket)			O	X	X	X	X	X	X	X	X									X	X		X				
14	<i>Lampsilis satura</i> (sandbank pocketbook) <sup>2,8</sup> (TWAP - SC)					X	X	X	X	X	X																	
15	<i>Lampsilis teres</i> (yellow sandshell)	?	X	X	X	X	X	O	X	X	X	X	X	X	X	O	X	O		X	X	X	X	X	X	X	X	X
16	<i>Lasmigona complanata</i> (white heelsplitter) <sup>2</sup> (TWAP - SC)			X	X					X										O								
17	<i>Leptodea fragilis</i> (fragile papershell)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		O									
18	<i>Ligumia subrostrata</i> (pond mussel)				X	X	X	X	X	X	X	X	X	X	X						X	X		X				
19	<i>Megaloniais nervosa</i> (washboard)				X	X	X	X	X	X	X	X	X	X	X	I				O	X	X	X	O	X			
20	<i>Obliquaria reflexa</i> (threehorn wartyback)			X	X	X	X	X	X	X	X																	
21	<i>Obovaria jacksoniana</i> (southern hickorynut) <sup>6,8</sup> (TWAP - SC)			X	X	X	X	X	X	X	X																	
22	<i>Plectomerus dombevanus</i> (bankclimber)				X	X	X	X	X	X	X																	
23	<i>Pleurobema riddellii</i> (Louisiana pigtoe) <sup>2,8</sup> (TWAP - SC)				X	X	X	X	X	X	X																	
24	<i>Popenaias popeii</i> (Texas hornshell) <sup>3,7,8</sup> (TWAP - FC)																								X	X	X	
25	<i>Potamilus amphichaenus</i> (Texas heelsplitter) <sup>2,8</sup> (TWAP - SC)						X		X	X																		
26	<i>Potamilus metnecktaii</i> (Salina mucket) <sup>2,8</sup> (TWAP - SC)																								X			
27	<i>Potamilus ohioensis</i> (pink papershell)		X	X	O	X				X	X	X		X														
28	<i>Potamilus purpuratus</i> (bleufer)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	?	X			I	I	I	?	
29	<i>Pyganodon grandis</i> (giant floater)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	?	X	X	X		X	O		I	X
30	<i>Quadrula apiculata</i> (southern mapleleaf)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	X	X	X	X	I				X
31	<i>Quadrula aurea</i> (golden orb) <sup>6,8</sup> (TWAP - SC)											O		X						X	X	X	X	X				
32	<i>Quadrula couchiana</i> (Rio Grande monkeyface) <sup>5</sup> (TWAP - SC)																								O			
33	<i>Quadrula houstonensis</i> (smooth pimpleback) <sup>6,8</sup> (TWAP - SC)											X	X	X	X													
34	<i>Quadrula mortoni</i> (western pimpleback)				X	X	X	X	X	X	X																	
35	<i>Quadrula nobilis</i> (gulf mapleleaf)			X		X	X		X	X	O																	
36	<i>Quadrula nodulata</i> (wartyback) <sup>3,4</sup> (TWAP - SC)			X		X	O		X																			
37	<i>Quadrula petrina</i> (Texas pimpleback) <sup>6,8</sup> (TWAP - SC)												X	X	X	X	O	X	O	X								
38	<i>Quadrula pustulosa</i> (pimpleback) <sup>6</sup>			X		X				X																		
39	<i>Quadrula quadrula</i> (mapleleaf)			X	X	X	X																					

X = Recent Occurrences (within last 30 years)  
O = Historical Occurrences (>30 years old)

\* = May be introduced  
I = Recently Introduced

? = Unknown if population still exists  
September 2009

# Freshwater Mussels of Texas Distribution Chart

Page	Family: Unionidae	Rivers																										
		1. Canadian River	2. Wichita River	3. Red River	4. Sulphur River	5. Big Cypress Bayou	6. Sabine River	7. Angelina River	8. Neches River	9. Trinity River	10. San Jacinto River	11. Brazos River	12. Little Brazos River	13. Navasota River	14. Colorado River	15. Concho River	16. San Saba River	17. Llano River	18. Pedernales River	19. San Marcos River	20. Guadalupe River	21. San Antonio River	22. Frio River	23. Nueces River	24. Rio Grande River	25. Devils River	26. Pecos River	27. Lavaca River
40	<i>Quincuncina (Quadrula) mitchelli</i> (false spike) <sup>5,8</sup> (TWAP - SC)										O			X		O	O	O	X	X					X		O	
41	<i>Strophitus undulatus</i> (creeper) <sup>2</sup> (TWAP - SC)				X	X	X	O	X	O	O	X			X	O	?	?		O	X	X						
42	<i>Toxolasma parvus</i> (lilliput)			X	X	X	X	X	X	X	X	X	X	X			?				X		X	X	X			
43	<i>Toxolasma texasiensis</i> (Texas lilliput)			O	O	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X		X
44	<i>Tritogonia (Quadrula) verrucosa</i> (pistolgrip) <sup>3</sup>			X	X	X	X	X	X	X	X	X	X	X	X	O	X	O	O	O	X	X						
45	<i>Truncilla cognata</i> (Mexican fawnsfoot) <sup>2,8</sup> (TWAP - SC)																								X			
46	<i>Truncilla donaciformis</i> (fawnsfoot) <sup>2</sup> (TWAP - SC)			X	X	O	O	X	X	X	X																	
47	<i>Truncilla macrodon</i> (Texas fawnsfoot) <sup>6,8</sup> (TWAP - SC)									?	X		X	X	X													
48	<i>Truncilla truncata</i> (deertoe)			X	O	X	X	X	X	X	X																	
49	<i>Uniomereus declivis</i> (tapered pondhorn)				X	X	O		X	X	X	X		X	X							X					O	
50	<i>Uniomereus tetralasmus</i> (pondhorn)		X	X	O	X	X		X	X	X	X	X	X	X					X	X		X					
51	<i>Utterbackia imbecillis</i> (paper pondshell)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	
52	<i>Villosa lienosa</i> (little spectaclecase) <sup>3,4</sup>				X	X	X	X	X	X	X																	

<sup>1</sup> Federal Endangered Species (FE)

<sup>2</sup> State Rank (S1) - Critically imperiled, extremely rare, very vulnerable to extirpation, 5 or fewer occurrences

<sup>3</sup> State Rank (S2) - Imperiled in state, very rare, vulnerable to extirpation, 6 to 20 occurrences

<sup>4</sup> State Rank (S3) - Rare or uncommon in state, typically 21 to 100 viable occurrences

<sup>5</sup> State Rank (SH) - Of historical occurrence in state. May be rediscovered.

<sup>6</sup> State Rank (SNR) - Not ranked to date

<sup>7</sup> Federal Candidate Species (FC)

<sup>8</sup> State Threatened Species

<sup>9</sup> State Rank (SNA) - Not applicable - species is not a suitable target for conservation activities

TWAP-SC = Species of Concern, TPWD Texas Wildlife Action Plan 2005 - [www.tpwd.state.tx.us/publications/pwdpubs/pwd\\_pl\\_w7000\\_1187a/](http://www.tpwd.state.tx.us/publications/pwdpubs/pwd_pl_w7000_1187a/)

X - listed in this drainage in the Texas Wildlife Action Plan 2005